S·A·E JOURNAL

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John A. C. Warner, Secretary and General Manager

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The Society is not responsible for statements or opinions advanced in papers or discussions at its meetings or in articles in the JOURNAL.

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S·A·E 30TH ANNIVERSARY

Summer Meeting

THE GREENBRIER
WHITE SULPHUR SPRINGS, WEST VA.

JUNE 16 – 21, 1935

S.A.E. 1935 Summer

The Greenbrier

★ 30TH ANNIVERSARY ★

Superlative Technical Program

Sunday, June 16th

6:30 P. M. *30th Anniversary Dinner*

PRESIDENT W. B. STOUT, Toastmaster

A gala banquet—a fitting celebration to start the 30th Anniversary Meeting—Past-Presidents will be the guests of honor—come early and truly enjoy a most unusual start of a very interesting Summer Meeting

followed by

Business Session
W. B. STOUT, Presiding

Monday, June 17th

9:30 A. M. *Transportation and Maintenance*

T. C. SMITH, Chairman

What's the Destination for Motor Transportation? — A. M. WOLF, Automotive Consultant, New York

9:30 A. M. *Aircraft-Engine*

P. B. TAYLOR, Chairman

The N.A.C.A. Investigation of Cowling and Cooling of Radial Air-Cooled Engines — CARLTON KEMPER and D. H. WOOD, National Advisory Committee for Aeronautics

Further Progress in Controlled Cooling of Radial Aircraft Engines—J. M. SHOEMAKER, Chance Vought Corp.; T. B. RHINES, United Aircraft Corp.; and H. H. SARGENT, JR., Pratt & Whitney Aircraft Co.

Evaluation of Variables Influencing Air Cooling of Engines—KENNETH CAMPBELL, Wright Aeronautical Corp.

2:00 P. M. *Aircraft-Engine*

ROBERT INSLEY, Chairman

Bringing the Italian Sky Down to Earth—M. E. MERRIMAN, Representative of Fiat, Detroit.

Comparison of Spark and Compression Ignition Engines for Aircraft Service—KENNETH A. BROWNE, Wright Aeronautical Corp.

8:00 P. M. *Aircraft*

C. H. CHATFIELD, Chairman

Flying The Lindbergh Trail—Sound Movies, courtesy Pan-American Airways, Inc.

10:30 P. M. *Water Carnival*

Tuesday, June 18th

9:30 A. M. *Truck, Bus and Railcar*

L. R. BUCKENDALE, Chairman

Diesel Power for Transportation—O. D. TREIBER, Hercules Motors Corp.

Motion pictures of Truck Operations at Boulder Dam

9:30 A. M. *Aircraft*

P. ALTMAN, Chairman

Design Problems and Methods for Large Flying Boats—I. I. SIKORSKY, Sikorsky Aircraft Corp.

The Work of the N.A.C.A. Tank—STARR TRUSCOTT, National Advisory Committee for Aeronautics.

2:00 P. M. *Aviation Demonstrations*

8:00 P. M. *Passenger Car*

L. P. KALB, Chairman

Stresses in Connecting-Rods and Bearings—W. R. GRISWOLD, Packard Motor Car Co.

Engine Knock Studied by Electro-Acoustical Instruments—NEIL MACCOULL, The Texas Co., and G. T. STANTON, Electrical Research Products, Inc.

Wednesday, June 19th

9:30 A. M. *Passenger Car*

C. R. PATON, Chairman

Mechanical Mind Reading (Transmissions)—JOHN SNEED, Sneed Engineering Corp.

"Sky-Hooks" for Automobiles (Suspensions)—W. S. JAMES, Studebaker Corp.

9:30 A. M. *Diesel-Engine*

L. C. LICHTY, Chairman

Analysis of Surges in Fuel Injection Pipes—K. J. DE JUHASZ, The Pennsylvania State College.

Performance of High-Speed Compression-Ignition Engines with Three Types of Combustion Chambers—ERNEST WHITNEY, National Advisory Committee for Aeronautics

2:00 P. M. *Field Day*

8:00 P. M. *Tractor and Diesel*

C. L. CUMMINS, Chairman

Agriculture and the Automotive Development—C. D. WIMAN, Deere & Co.

Diesels on Canadian Roads—H. L. WITTEK, Consulting Engineer, Toronto.

Thursday, June 20th

9:30 A. M. *Passenger Cars and Bodies*

W. C. KEYS, Chairman

Cellular Rubber Cushions the Car—H. E. ELDEN, Dunlop Tire & Rubber Co.

Discussion on Body and Material Features—W. B. STOUT, Stout Engineering Laboratories.

9:30 A. M. *Fuel Volatility*

H. F. HUF, Chairman

A Forgotten Property of Gasoline—J. O. EISINGER and D. P. BARNARD, Standard Oil Co. of Indiana.

Economics of Fuel Volatility—H. W. FIELD and M. J. FOWLE, Atlantic Refining Co.

Fuel Volatility Limitations Imposed by Vapor Lock—NEIL MACCOULL and E. M. BARBER, The Texas Co.

What Price Dynamite?—C. H. JORGENSEN, Delco-Remy Corp.

Trends in Automobile Design as Influenced by Fuel Volatility—J. M. CAMPBELL, W. G. LOVELL and T. A. BOYD, General Motors Corp.

(Some of these papers and some discussion may be carried over to Friday morning.)

8:00 P. M. *General*

A. L. BEALL, Chairman

Railroad Equipment Possibilities—J. B. EASTMAN, Federal Coordinator of Transportation

10:30 P.M. *Grand Ball*

Friday, June 21st

9:30 A. M. *Fuels and Lubricants*

D. P. BARNARD, Chairman

Report of Extreme Pressure Lubricants Subcommittee—W. S. JAMES, Studebaker Corp.

(Some papers and some discussion may be carried over from the Thursday morning Fuel Session.)

Meeting, June 16-21

White Sulphur Springs, W. Va.

★ 30TH ANNIVERSARY ★

Special Events

Thirtieth-Anniversary Dinner

Past-presidents of the Society will give short talks about the things which interest them the most . . . informal entertainment and good fellowship in a formal setting . . . a get-together meeting which promises to be one of the most interesting in the history of the Society

International Exhibit

Scores of things you never knew 'til now arranged in a pictorial exhibit . . . contributions from many of our members overseas . . . interesting historical material from many domestic sources . . . a brand-new feature for an outstanding meeting

Don't Miss---

The Aircraft Demonstration on Tuesday
The Transportation Review
Field Day on Wednesday Afternoon
Water Carnival Monday Night

COMMITTEE MEETINGS

Sunday—June 16th

9:30 A. M.	Brake Committee
12:00 Noon	Council
2:00 P. M.	Ignition Research Subcommittee

Monday—June 17th

8:00 A. M.	Membership and Sections
8:00 A. M.	Aircraft Engine Activity
12:00 Noon	Transportation and Maintenance Activity
12:00 Noon	C.F.R. Aviation Gasoline Detonation
2:30 P. M.	Highway Research Subcommittee
6:30 P. M.	Truck, Bus and Railcar Activity

Tuesday—June 18th

8:00 A. M.	Motor Vehicle Design
8:00 A. M.	Passenger Car Activity
12:00 Noon	Publication Committee
12:00 Noon	Motor Truck Rating

Tuesday—June 18th—(Continued)

12:00 Noon	Aircraft Activity
4:30 P. M.	Oiliness Research Subcommittee

Wednesday—June 19th

8:00 A. M.	Riding Comfort Research Subcommittee
8:00 A. M.	Meetings Committee
12:00 Noon	Diesel Engine Activity

Thursday—June 20th

8:00 A. M.	Standards Committee
8:00 A. M.	Passenger-Car Body Activity
8:00 A. M.	Front Wheel Alignment
12:00 Noon	Fuels and Lubricants Activity
2:00 P. M.	E. P. Lubricants Research

Friday—June 21st

12:00 Noon	Research Committee

Hotel reservation blank, railroad timetable and tariffs, and reduced fare certificate are enclosed with this bulletin

Last Call

Make Your Reservations NOW!

"It paid real dividends."—"Technical fare enough to satisfy the appetite of any engineer"—"Unusually broad in its coverage"—"Up to the minute in its timeliness"—"Interesting to the nth degree."

These are the comments that you are going to hear from those who attended the 30th Anniversary Summer Meeting.

Look over the program and see if you don't agree. Read the abstracts of some of the papers to be presented.

Can you afford to stay away?

Besides such a superlative technical session line up there will be just enough added recreational features to make your stay more enjoyable.

Golf—Tennis—Bridge—Swimming—Dancing—Special Entertainment for Ladies

Fly to White Sulphur Springs

S. A. E. Headquarters can give you complete information about the good Greenbrier Airport. Write for it.

News of the Society

"Business Belongs to Stockholders" Says Knudsen at Dramatic Meeting

• Detroit

"MANAGEMENT functions belong to management, and to nobody else.

"The business belongs to the stockholders, and to nobody else.

"Any attempt to take the country's industries and make them a political football in Congress on the order of the tariff and taxation system will fail as long as democratic government endures with the support of thinking and loyal citizens."

With these words—spoken forcefully in slow measured tones—W. S. Knudsen, executive vice-president, General Motors Corp., at the Detroit Section meeting on May 13 emphasized the permanence in his mind of basic principles involved in management-labor relationships. As Mr. Knudsen was speaking these words to S.A.E. members in Detroit, striking workers of the Chevrolet transmission plant in Toledo were voting 732 to 385 to return to work on the basis of a settlement offer which had been presented by Mr. Knudsen and his associates a few hours before.

The coincidence of events made this particular Detroit Section meeting one of the most dramatic in years and nearly 800 members and guests listened intently while Mr. Knudsen hammered home point after point of management principle underlying the current relationships between employers and labor and commented on the place of the engineer in the automobile industry.

Clyde R. Paton, chief engineer, Packard Motor Car Co., and retiring Detroit Section chairman, presided at the meeting.

Kettering Lauds S.A.E.

C. F. Kettering, vice-president, General Motors Corp., was toastmaster and spoke vigorously of the need for giving more scope to research projects as a form of insurance rather than as an aspect of immediate manufacturing and design problems. He paid a high tribute to the Society when he said: "I know of no group of men whose respect I would rather have than that of the men gathered here in this room." The meetings of the Society in general, he said, have benefited materially the engineering progress of the industry.

Mr. Knudsen stressed the fact that mass production has brought higher responsibilities to the engineer.

"The engineer," he said, "is one of the most important factors in the company's success. He cannot be purely a mechanical engineer; if he is, he is likely to be trailing competition. He must be a highly progressive thinker; he must be willing to travel an independent road; he must be a high-grade organizer; he must have a thorough knowledge of manufacturing costs and processes, and, last but not least, he must sense what the consumer demands, not only when the car is bought, but after it has seen years of service and is ready to go on relief through the medium of the used car lot. I know this is a big order, but it is a fact."

Defines Engineers' Functions

Developments in the motor car, Mr. Knudsen believes, will be just as great in the next 20 years as in the last 20. Cooperation between the shop and the engineering department is essential to economic success, he said, emphasizing the principle that "you will never make money in business hating somebody." Willingness of engineers to go into the field and really observe the results of their efforts helps materially in getting the best final results, he stated, adding that the dealer often can give the engineer good information.

Touching on the much-discussed speed-of-production problem, Mr. Knudsen observed that "if you give the American workman the proper tools and the proper flow of material, both ingoing and outgoing, you won't have to worry much about the speed of production. Speed as such produces little or nothing. Correct design and accuracy in manufacturing are what makes high production possible."

"The depression," he went on to say, "made it necessary for us to do many things which we would not do in ordinary times. We learned a lot from it, and we are reaping the harvest—good or bad."

He scouted the theory of trying to divide all the hours of work available by the number of people.

Purchasing Power Needed

Expressing great hopes for the future of the motor car business because nothing has been invented which replaces the automobile, Mr. Knudsen said that the only danger lies in the reduced purchasing power of the people "which might be made a possibility by our parlor-pink statesmen who are willing to advocate that everybody should be poor so that nobody may get rich.

"I still have hopes," he concluded, "that the sane people in this great country of ours are still in the majority, and will eventually puncture this great theory of scarcity in the way that it deserves. . . . All the talk which the philosophers may make about the decline of Western civilization will have no influence whatsoever on America's great future."

Preceding Mr. Knudsen's address, William Edward Hann of Harness-Dickey-Pierce and Hann, talked interestingly of "Inventions—past and present; sound and ridiculous."

The meeting was the last which will be held during the current Section year and marked retirement from office of the 1934-1935 Section officers. Section members presented to retiring chairman Clyde Paton a gift in appreciation of his services and efforts. F. W. Marschner, long time treasurer of the Detroit Section, was similarly honored.

Chairman-elect Peter Altman, University of Detroit, spoke briefly of his hopes for continuing progress with the activities of the Section next year.

Beardsley Presents Data on New Power-Mixture Control for Planes

• Hartford Regional Meeting

THE right color of ink is beginning to show in the management reports of the aviation industry, which indicates there will be no foolish curtailment of engineering expense. Donald L. Brown, president, United Aircraft Corp., made this assertion as the lead-off speaker at the Second Hartford Regional Meeting of the Society, held April 26. Mr. Brown's talk was addressed to about 150 members and guests assembled for a program of interest.

Following Mr. Brown on the program Guy E. Beardsley, Jr., project engineer, Pratt & Whitney Aircraft Co., presented a paper on "The Hiscock Automatic Power and Mixture Control." It was the first presentation anywhere of technical data on the Hiscock device, which recently completed a grueling test on the Sikorsky plane which made a prospecting flight to Honolulu.

C. Fayette Taylor, professor of automotive engineering, Massachusetts Institute of Technology, rounded out the program with a paper on "Stresses in Aircraft Engine Parts" which did much to upset conventional ideas about stress analysis. Robert Insley, sales engineer, Pratt & Whitney Aircraft Co., introduced Mr. Brown, and Andrew V. D. Willgoos, chief engineer, Pratt & Whitney Aircraft Co., was chairman of the technical session which followed the dinner at which Mr. Brown spoke.

In his address Mr. Brown emphasized the fact that a particular engineering achievement is seldom the accomplishment of one man alone. "For instance," he said, "the way has been paved for Transatlantic commercial flight, it will come certainly within the next two or three years, he indicated, and when it does credit for its accomplishment will have to be distributed in a great many directions. This is true also of the two outstanding aviation accomplishments of recent months: The Douglas plane in regular Transcontinental service and the Sikorsky plane which recently completed a test flight to Honolulu in anticipation of scheduled Transpacific service. Mr. Brown indicated strong interest in the possibility of forming an S.A.E. Section in Hartford and said it would have his unqualified support.

Mr. Beardsley's paper represented a summary of two and a half years of work on the Hiscock automatic mixture control which has been brought to a successful completion by himself and his assistants. In introducing his paper he stated that variations in fuel consumption of as high as 25 per cent are obtained on the same airplane when operated by different pilots. Because of this fact, he said, the importance of regulated fuel consumption is becoming more and more evident with the advent of high-powered engines and long range airplanes. Where formerly, adjustment of the mixture control

could be left to the discretion of the pilot, we have now reached a stage where the uncertainty of this method becomes a serious handicap.

The late Thorp Hiscock evolved a basic idea of accomplishing power of limitation and mixture control with one unit. He proposed by throttling the air entering the carburetor to maintain the density of the air entering the venturis equivalent to that at an altitude of, say, 7000 ft. Thus the carburetor would deliver even though the airplane might be at sea level a mixture of the same fuel-air ratio that it would normally deliver at 7000 ft. Mr. Hiscock further proposed to position the mixture control so that with a conventional carburetor a uniformity of fuel consumption would be maintained below the altitude norm. Inasmuch as throttling of an engine can be done at any point in the induction system, the standard carburetor throttle could be left open at all times and both the power and mixture automatically controlled.

Mr. Beardsley described in some detail the methods by which Mr. Hiscock's conceptions were carried to successful conclusion.

During flight test work with a power and mixture control unit set to a critical altitude of 7200 ft. a test was made to determine at what altitude use of the manual mixture would be required. With the control delivering a lean best power mixture when below the critical altitude, full reach operation was checked at several altitudes and not until 15,000 ft. was reached, was noted even a tendency for engine revolutions to increase when leaning out. Theoretical calculation based on these figures indicated that with a critical altitude of 11,000 ft. best power operation should be experienced with the manual mixture adjustment to approximately 20,000 ft. of altitude. Mr. Beardsley presented the following conclusions relative to the dual function of the automatic device:

As a Mixture Control

1. Maintaining a constant density of the air entering the carburetor produces a practically constant fuel-air ratio delivered by the carburetor through the normal operating range.

2. Above the critical altitude of the regulating device enriching with increases in altitude similar to normal carburetion will be experienced. Within the altitude range used for normal commercial operating the enrichment above the critical altitude will not exceed the best power mixture strength. Inasmuch as operation above the critical altitude of necessity entails a reduction of the full throttle horsepower the hourly fuel consumption will decrease.

3. For military work or other work requiring ascent to altitudes higher than in 2 above, a manual mixture control should be provided.

4. A more desirable shape of fuel curve is obtained at critical altitude than with a self-compensating mixture control applied to a standard carburetor in that the same fuel-air ratio is delivered whether at part throttle or full throttle.

As a Power Control

1. With a constant speed propeller power regulation equivalent to any device maintaining constant manifold pressure is obtained. Such regulation is more satisfactory than that obtained with a throttle stop or gate.

2. With a two-position or fixed-pitch propeller power regulation slightly inferior to that available with constant manifold pressure is obtained due to changes in manifold pressure with changes in R.P.M. The result obtained, however, is still superior to that available with a throttle stop.

3. For commercial or military operation where an extended cruising range with limited maneuverability is desired, this device offers an excellent solution.

In his talk on stress analysis Professor Taylor said that impact tests were valuable in showing characteristic differences or imperfections in specimens otherwise showing the same characteristics. They do not correlate, however, with structural failures in terms of endurance limit.

The property of ductility does not correlate with fatigue limits in spite of the widespread belief to the contrary, he indicated. Ductility is not important with relation to failures.

Charles H. Chatfield, vice-president of the Society representing aircraft engineering, and chairman of the technical advisory committee, United Aircraft Corp., with C. B. Whittelsey, executive vice-president, Hartford Chamber of Commerce and a past-treasurer of the Society, headed the list of sponsors for the Hartford meeting. As at the first meeting, the Metropolitan and New England Sections sent delegations through the courtesy of Sid G. Harris, chairman of the Metropolitan Section, and C. E. Batstone, chairman of the New England Section. Before the dinner in connection with the meeting ended, Mr. Insley stated that much interest had been expressed in the formation of a Hartford Section and that all those present who wished to advance the idea should express their sentiment in writing to S.A.E. headquarters for presentation to the Council.

(News of the Society continued on page 22)

Transportation and Maintenance Activity Committee—1935

FOLLOWING are the names of members who will serve on the Transportation and Maintenance Committee which has just been appointed:

Chairman—

T. C. Smith,
Engineer, Motor-Vehicles and Construction Apparatus, American Telephone & Telegraph Co., Inc.

Eastern Vice-Chairman—

Fred L. Faulkner,
Manager Automotive Department, Armour & Co.

Western Vice-Chairman—

William H. Fairbanks,
Motor-Vehicle Superintendent, Southern California Telephone Co.

Chairman Membership Committee—

Theodore L. Preble,
Supervisor, Automotive Equipment, Tide Water Oil Co.

Chairman Meetings Committee—

Austin M. Wolf,
Automotive Consultant

Edward L. Bauer,
Assistant Superintendent,
Municipal Garage, St. Louis, Mo.

Carleton H. Bolin,
Motor-Vehicle Superintendent,
Pacific Telephone & Telegraph Co.

Clinton Brettell,
Superintendent of Garages,
R. H. Macy & Co.

Alfred F. Coleman,
Manager, Motor-Vehicle Department,
Socony-Vacuum Oil Co.

Robert J. Collins,
Superintendent of Transportation,
Kansas City Power & Light Co.

William J. Cumming,
General Superintendent,
Surface Transportation Corp.

Henry Dakin,
Superintendent of Buildings and Supplies,
Michigan Bell Telephone Co.

Henry L. Debbink,
Superintendent Gasoline Vehicles,
Milwaukee Electric Railway and Light Co.

Harley W. Drake,
Superintendent of Garages,
Portland Gas & Coke Co.

Frederick K. Glynn,
Engineer,
American Telephone & Telegraph Co., Inc.

George E. Gray,
Manager, Automotive Department,
Shell Eastern Petroleum Products, Inc.

Howard R. Grigsby,
Superintendent of Transportation,
Oklahoma Gas & Electric Co.

O. Arnold Hansen,
Automotive Engineer,
Linde Air Products Co.

Francis I. Hardy,
Industrial Engineer and Trucking

Herbert R. Holder,
Superintendent,
Auto Bus Department, Montreal Tramways Co.

Frederick C. Horner,
Assistant Vice-President,
General Motors Corp.

Burton J. Lemon,
Automotive Engineer,
U. S. Rubber Products, Inc.

Albert A. Lyman,
Automotive Engineer,
Public Service Coordinated Transport

Harry O. Mathews,
Superintendent, Motor Equipment,
Illinois Bell Telephone Co.

John G. Moxey,
Transportation Engineer,
Sun Oil Co.

Leonard V. Newton,
Automotive Engineer,
Byllesby Engineering & Management Corp.

John M. Orr,
General Manager,
Equitable Auto Co.

Edward S. Pardoe,
Superintendent, Bus Operations,
Capitol Traction Co.

Arthur R. Platt,
Proprietor, Pittsburgh

George O. Pooley,
Superintendent of Buildings,
Motor Vehicles and Supplies,
Chesapeake & Potomac Telephone Co.

Rodman S. Reed,
Chief Engineer, Brockway Motor Co.

J. Verne Savage,
Shop Superintendent,
City of Portland Municipal Shop

Arthur J. Scaife,
Consulting Field Engineer,
White Motor Co.

Marion F. Steinberger,
Manager, Highway Transportation,
Baltimore & Ohio Railroad

Edward L. Tirrell,
Automotive Engineer,
Utility Management Corp.

John F. Winchester,
Manager, Automotive Department,
Standard Oil Co. of New Jersey

Edwin C. Wood,
Superintendent, Transportation,
Pacific Gas & Electric Co.

What Members Are Doing

Russell S. Begg, chief engineer, Midland Steel Products Co. for several years, has just joined the central engineering staff of General Motors Corp. where he will work on a special engineering assignment. Mr. Begg was at one time chief engineer of the Jordan Motor Car Co. and later chief engineer of the Budd Wheel Co. He is succeeded by

Gerhard C. R. Kuiper who becomes chief engineer of the Midland Steel Products Co. Mr. Kuiper was formerly assistant chief engineer at Midland.

George S. Piroumoff, formerly vice-president and engineering executive of the Brockway Motor Co., Inc., was elected president of the company at a meeting of the board of directors on April 19. Mr. Piroumoff, who has been a member of the Society since 1925, joined Brockway in 1929. In addition to serving as president of the company, he will be a member of the board of directors.

T. M. Nevin, formerly test engineer, Pierce-Arrow Motor Car Co., Buffalo, N. Y., has become test engineer for Budd Wheel Co., Detroit, Mich.

A. S. Van Halteren, formerly with the Firestone Steel Products Co., Akron, Ohio, as development engineer is now sales engineer for the Motor Wheel Corp., Lansing, Mich.

Victor R. Ellison is now in the Engineering Department of the International Harvester Co., Ft. Wayne, Ind. He was formerly designer, General Aviation Mfg. Corp., Baltimore, Md.

Herbert F. Sauer

Herbert F. Sauer has been appointed manager of the Chicago branch of the Electric Storage Battery Co. Formerly he was manager of the Cleveland branch of the company.

John A. Howlett has joined the Research Engineering Department of Sears, Roebuck Co. at Chicago, Ill. He was formerly technical lubrication engineer, Magnolia Petroleum Co., Dallas, Tex.

John F. McMahon, formerly maintenance engineer, Checker Cab Mfg. Corp., New York City, is now engineer, Yellow Products Corp., New York.

Roy E. Cole is now executive engineer, Studebaker Corp., South Bend. He was formerly with the Cole Engineering Co., Detroit.

J. W. Spray, formerly vice-president, Timken Roller Bearing Co., Canton, Ohio, is now associated with the Bower Roller Bearing Co. of Detroit.

Raymond L. Spragle is now automotive engineer, American Car and Foundry Co., Berwick, Pa. He was formerly automotive engineer, J. G. Brill Co., Philadelphia.

C. S. Kegerreis has been named vice-president and treasurer of the Kegerreis Sales Corp., Elkhart, Ind. He was formerly chief engineer, Holley Carburetor Co., Detroit.

A. C. Olander has joined the South Bend Lathe Works as sales engineer. He was formerly associated with the Studebaker Sales Corp. as assistant to the sales promotion and advertising manager.

A. T. Gregory, formerly test engineer, Wright Aeronautical Corp., Paterson, N. J., is now technical engineer with the Ranger Engineering Corp. at Farmingdale, N. Y.

William H. Kelley is now associated with Kelley's Automobile Service Co., Stapleton, Staten Island, as service manager. He was formerly service manager, Island Motor Corp., Stapleton.

G. A. Worrall, formerly district manager, White Co., Albany, N. Y., is now district manager for the Keebler-Weyl Baking Co., Philadelphia, Pa.

John J. Nargi, formerly draftsman, Chevrolet Motor Co., Detroit, is now connected with the Continental Motors Corp., Detroit, as draftsman and mathematician.

B. H. Gerker is connected with the Carter Carburetor Corp., St. Louis, as production engineer. He was formerly engineer with the Chevrolet Motor Co., Flint, Mich.

P. E. Biggar has resigned as chief designer, Leyland Motors Ltd., Leyland, England, and after a tour of the Continent will return to Toronto, Ontario, where he will practice as a consulting engineer.

Robert A. Darby has become associated with the Curtiss Aeroplane & Motor Co., as an assistant stress analyst. He was formerly stress analyst, North American Aviation, Inc., Dundalk, Baltimore.

William B. Todd has been elected vice-president in charge of sales as well as a director of the Jones & Laughlin Steel Corp., Pittsburgh, Pa. He was formerly general manager of sales.

W. B. Todd

Roy F. Anderson has been connected with the Fisher Body Corp. since March 1, on the engineering Staff of P. J. Mauck, chief engineer.

Edward D. Herrick is now executive engineer with the Lycoming Mfg. Co., Williamsport, Pa.

Maxwell N. Halsey formerly connected with the National Bureau of Casualty & Surety Underwriters, New York, N. Y., is now associated with the Bureau for Street Traffic Research, Harvard University, Cambridge, Mass., as assistant director.

A. H. Wood, formerly automotive engineer, Conger Lehigh Co., Ltd., Toronto, Ontario, is now engaged as automotive safety engineer, in charge of the newly created safety engineering department of the Canadian General Insurance Co. and the Toronto General Insurance Co., Toronto, Ontario.

Grover C. Loening, a pioneer in aircraft invention and president of the Grover Loening Aircraft Co., Inc., Garden City, L. I., has been appointed chairman of the American Engineering Council's Committee on Aeronautics.

N. K. G. Tholand, president, Ekstrand & Tholand, Inc., New York City, has moved his office to 441 Lexington Ave., New York.

Dr. Alvin C. Purdy of Bull & Roberts, consulting chemists, has moved to 117 Liberty Street, New York.

To Prospective Paper Presenters

During the week of the Summer Meeting, various committees will give consideration to the question of papers for the 1936 Annual Meeting, to be held next January. The Meetings Committee urges that members who have material for papers, or who have already prepared papers on timely automotive topics in any of the many branches in which the Society is interested, write to S.A.E. Headquarters, telling of the availability of their material and giving, in each case, a full explanation of the contents of the proposed paper.

Letters should be addressed to the Sessions Secretary, Society of Automotive Engineers, 29 West 39th Street, New York City; and each communication will be brought before the Professional Activity Committee for whose attention it is intended.

Guggenheim Medal Awarded

The seventh award of the Daniel Guggenheim medal was made May 3 to William Frederick Durand "for notable achievement as a pioneer in laboratory research and the theory of aeronautics and for distinguished contributions to the theory and development of aircraft propellers." Dr. Durand is professor emeritus of mechanical engineering at Stanford University.

The Daniel Guggenheim medal was established in 1928 and presented under the joint sponsorship of the Society of Automotive Engineers and the American Society of Mechanical Engineers. Major E. E. Aldrin, Standard Oil Co. of New Jersey, and Arthur Nutt, vice-president of the Wright Aeronautical Corp., headed the 1935 Board of Award.

Behind the Scenes With

Diesel Fuel Research Committee

THE Joint S.A.E.-A.S.M.E. Diesel Fuel Research Committee has been discharged by action of the Councils of the American Society of Mechanical Engineers and the Society of Automotive Engineers, upon the recommendation of their respective research committees.

Two groups have organized to maintain interest in this subject and to promote research in this field. One is an informal group, known as the Volunteer Group for Cooperative Research on Fuels for Compression-Ignition Engines, which, under the chairmanship of T. B. Rendel, Shell Petroleum Corp., and with C. H. Baxley of Sinclair as secretary, is conducting a cooperative test program on a modified form of the C.F.R. Engine; and the other is a committee of the A.S.M.E. Oil and Gas Power Division that is interested in the fuel problem of the large Diesel engine.

Highways Research

THE Highways Research Subcommittee has continued its cooperation with Joseph B. Eastman, Federal Coordinator of Transportation, in connection with his study of problems connected with highway utilization.

Riding Comfort

A DEFINITE plan for correlating existing instrumentation and test methods into a practical means for measuring riding comfort and answering the question

"What is the best ride?" is being evolved by a small working group within the Riding Comfort Research Subcommittee.

Extreme-Pressure Lubricants

ARRANGEMENTS for producing twenty testing machines have been effected by the Extreme-Pressure Lubricants Research Subcommittee with the Highway Trailer Co., Edgerton, Wis. These machines are being purchased upon approval of the E-P Lubricants Executive Committee by active participants in a cooperative test program to work out the proper procedure for operation and correct any difficulties that may be inherent in the design of the machine. A suggested tentative procedure and instructions as to the method of operating the machine are being worked out by a subsubcommittee, and a group of test oils will be furnished with and their cost included in the purchase price of each machine.

A Committee report including such data as may be obtained up to the time of the Summer Meeting will be presented by Chairman W. S. James at White Sulphur on June 21.

Front Wheel Alignment

A REVISION of "Basic Definitions for Camber, Caster, Toe-In and King-Pin Inclination" rearranged with sketches, together with an appendix covering suggested limits for lost motion in the steering system, and for wheel-bearing and knuckle-pin bushing wear have been approved by the Front Wheel Alignment Research Subcommittee and sent out to representative passenger car, truck and bus engineers and fleet operators for further criticism.

A questionnaire for the collection and compilation of 1935 front wheel alignment specifications on camber, caster, toe-in

and king-pin inclination of passenger cars, trucks and buses has been circulated with a view to making these data available for publication at an early date.

Crankcase Oil Stability

A SMALL working group composed of men actively engaged in efforts to solve the problem of crankcase oil stability has been appointed by Chairman J. B. Fisher of the Crankcase Oil Stability Research Subcommittee, in accordance with authorization given by the Subcommittee at its Jan. 16 meeting.

The collection and assembling of available data into a report and the formulation of a suggested procedure for the further investigation of crankcase-oil stability are the tasks assigned to this Subsubcommittee, with a request that they pursue this assignment immediately.

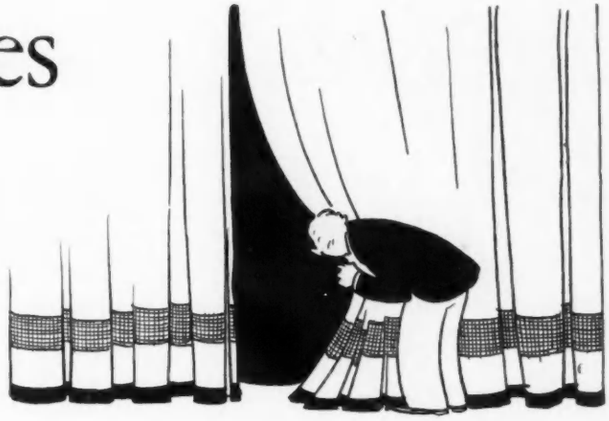
C.F.R. Detonation

A PAPER on the effect of different mixture temperatures on the correlation of the 1934 Uniontown fuels was released by the Cooperative Fuel Research Committee, at its May 7 meeting, for presentation at the Mid-Year Meeting of the American Petroleum Institute at Tulsa, May 14 to 16.

This report was prepared by a special sub-group within the Detonation Subcommittee, headed by Neil MacCoull, appointed some time ago to investigate this subject and supply laboratory data to round out the information obtained at Uniontown.

The Cooperative Fuel Research Committee has also author-

the Committees



ized the Waukesha Motor Co. to make the following mechanical changes in the A.S.T.M.-C.F.R. knock-testing apparatus:

1. The insertion of a distance-reading oil temperature thermometer in the crankcase
2. The incorporation of a switch to bypass the manifold heater circuit
3. The incorporation of an ammeter in the manifold heater circuit
4. The insertion of a waste-type centrifugal oil filter, and short circuit

The Committee emphasized that the action authorizing these changes is not retroactive since they have no effect on ratings obtained. These items will be included on new Engines and will be available as additional or replacement equipment on units now in use.

Ignition Research

THE Ignition-Research Subcommittee, in undertaking the formulation of a method of spark-plug testing suitable for incorporation in purchase specifications, has exchanged within its membership individual suggested methods of procedure which will form the basis for discussion on this subject by the Subcommittee as a whole at an early date.

1935 Handbook Mailed

CONTAINING in definitive form results of three of the Society's important standards projects completed during the year 1934, and many other important revisions and additions, the 1935 edition of the S.A.E. HANDBOOK is now being distributed. Most of the edition of 7000 is going to members of the Society in nearly every country of the world but copies are available at $5 each to others who have made use of the HANDBOOK in the past.

Of the new material in the HANDBOOK, perhaps the most important inclusion is a complete revision of the Iron and Steel Specifications and the Non-Ferrous Metals Specifications. The last complete previous revision in these categories was made in 1922. Progress in the art since that time required that the Iron and Steel Division of the S.A.E. Standards Committee spend over a year in complete revision and modernization of specifications, chemical compositions and heat treatments in order to produce a new epitome of the subject which shall be of maximum benefit to the many industries using it.

Other new material in the HANDBOOK includes revised tables of screw threads and bolts and nuts which have been established as American standard under the sponsorship of the S.A.E. and the A.S.M.E. New specifications have been set up for the straight 8, 12 and 16 thread-per-inch classifications covering Class 2 and 3 fits in the 8 and 12 pitch series and Class 3 fits in the 16-thread series. There has been added to this group a series of valuable tables covering special-pitch threads in Class 2 and 3 fits and thread diameters from No. 10 to 1½ inches inclusive.

Complete explanation is given in the HANDBOOK of the three cost classifications or cost record plans designed to serve different sizes and types of motor-vehicle fleet operations. A separately published pamphlet of this report includes types of all the necessary forms that are required for using the Uniform Motor-Vehicle Operating Cost Classification.

Another set of forms which is expected to find wide use in the automotive industry provides for uniform reporting and filing of motor-vehicle lubrication data. By obtaining a supply of this S.A.E. standard form to cover his new vehicle models, the motor-vehicle manufacturer will be enabled to send to every source requiring the information complete standardized and accurate data about the lubrication of his vehicles, at a minimum of cost and effort.

Spark-plug specifications appearing in previous editions of the HANDBOOK have been revised and brought up to date and are thoroughly in accord with modern practice in this branch of the automotive engineering art.

Revised specifications for reflex reflectors used on motor-vehicles and in laboratory tests of electric headlamps are also included.

Because of the frequent changes in tire and rim practices, the obsoleted previous specifications have been omitted, especially as up-to-date specifications are obtainable through the Tire and Rim Association.

Data have been included covering the oval diameters for tanks on fuel tank trucks. These data have been added as a result of a cooperative project with the American Petroleum Institute and a Committee of the Tank Manufacturers lasting two years.

The storage battery specifications have been brought up to date and valuable new information on the method of testing has been included in the 1935 edition of the HANDBOOK.

The complete report of the Automotive Transportation Code Committee has been published in the 1935 edition of the HANDBOOK as a guide in connection with motor-vehicle regulatory and similar matters.

The new edition contains 672 text pages and 24 pages of index.

First published in 1911 the S.A.E. HANDBOOK was then issued in loose-leaf pamphlet form. Beginning with the 1926 edition it was published in permanent binding but in a smaller size than the present edition whose form was established with publication of the 1933 edition. Distribution of the HANDBOOK is not limited to the automotive industry. The Society has in its files letters indicating the use of S.A.E. standards in scores of industries having no connection with automotive production.

Papers from Recent Meetings in Digest

HERE are digests of papers presented at recent Section or Regional Meetings of the Society.

* * * *

Some of these papers will be printed in full in the S.A.E. JOURNAL.

Mimeographed copies of *all of them* will be available, until current supplies are exhausted, at a cost of 25 cents per copy to members; and at 50 cents per copy to non-members. Orders for mimeographed copies must be accompanied by remittance and should be addressed to Sessions Secretary, Society of Automotive Engineers, 29 West 39th St., New York.

Metropolitan Section Paper

Monday, March 11

Principles of Fleet Operation—*T. L. Preble, supervisor, automotive transportation, Tide Water Oil Co.*

THE paper treats the subjects of organization control, efficient use of equipment, maintenance, cost accounting, retirement of old equipment, and selection of new equipment.

The functions of the automotive department of a business should include selection, allocation, maintenance, and retirement of vehicles, together with technical supervision over their operation. Adequate authority must be granted to the transportation executive to secure satisfactory coordination of these functions.

Time, mileage, and the amount of product delivered or of work done, are the three factors of usage-economy. Night maintenance service, unit replacement and preventive maintenance are advocated. Cost accounting should be essentially a matter of penetration into useful details; it should be not only descriptive but interpretive.

Sound judgment—based upon factors of obsolescence, variable costs, trade-in valuations, and profitable application in terms of the factors of usage-economy—should govern the retirement of old equipment. The creation of standards upon which to base purchases of new equipment is stated to be highly desirable, and seven types of such standardization are enumerated.

Philadelphia Section Paper

Wednesday, March 13

Vacuum Power Brakes—*Henry D. Hukill, technical supervisor, Bendix Products Corp.*

THE author states that commercial development of the BK vacuum power-brake dates back to 1916. Early equipment was all of the atmospheric suspended type. Increases in power, speed and weight of automotive haulage units, together with forecasts of four-wheel brakes and the general usage of trailers in cross-country service, definitely indicated the practical limitations of any form of atmospheric suspended unit. This led, in 1923, to the development of the vacuum suspended form of vacuum power-brake equipment, which is an exclusive design covered by basic patents.

The fundamental operating principle of the atmospheric suspended type of power brake is stated and illustrated diagrammatically, together with a typical installation which incorporates a diaphragm-type chamber. Two inherent features of all BK vacuum suspended installations are (*a*) that the vacuum unit is always supplemental to physical brake-application means and physical application is always possible; and (*b*) that the vacuum check-valve maintains a maximum vacuum reserve in the system and permits a power application after the engine has stopped. The brake valve commonly used with such installations is illustrated and described.

Other features considered are: Tandem operation of power cylinders on trailers in perfect synchronization with the tractor unit, several different forms of installation, a super-power vacuum-system for large-capacity vehicles and multi-unit trains, and a recently developed Bendix continuous-duty rotary vacuum-pump for Diesel-engined units or extremely heavy duty in mountainous territory.

Buffalo Section Paper

Tuesday, April 9

The Practical and Economic Application of Special Atmospheres in the Heat Treatment and Brazing of Metals—*C. L. West, sales and research engineer, Electric Furnace Co.*

THE paper states that atmospheric control is an element of major importance today in the planning of all new heat-treating equipments as well as in modernizing existing equipments for the purpose of meeting present-day requirements.

The application of atmospheric controlled furnaces to the heat treatment of metals is not necessarily new, but its acceptance has advanced

appreciably only during the last three years, due to the development of equipment and methods, permitting the production of suitable atmospheric gases for elimination of oxidization at very low costs.

The gases used for such operations as bright annealing, brazing and other kindred operations prior to about three years ago were for the most part tank hydrogen, or a gas composed of approximately 75 per cent of hydrogen and 25 per cent of nitrogen, which gas is produced by the dissociation of ammonia. Due to their high cost, the gases referred to necessarily had to be used very sparingly, which resulted in the necessity for very elaborate furnace designs, particularly with regard to entrance and exit openings in order to conserve their use.

The development of "Effurno Gas" by the research department of the author's company is reported upon and its applications are described. Other subjects are treated under the headings: Practical furnace designs incorporating controlled atmospheres, and clean hardening and carbon control. Eight types of furnace equipments which have been applied practically to the processes enumerated in the paper are illustrated and described with regard to their mechanical features.

No. California Section Paper

Tuesday, April 9

Some Flying Problems—*Elliott G. Reid, Guggenheim Aeronautical Laboratory, Stanford University.*

THE effects of winds upon the scheduled operations of airplanes are first discussed, it being stated that the problem of flying a modern transport plane against a head wind is quite complicated. If the increase of cruising speed with altitude is greater than that of wind speed, time will be gained by "going upstairs"; but if the wind speed increases very rapidly with altitude, the higher the plane flies the poorer time it makes. Hence, complete meteorological services that provide adequate information on upper-air conditions are necessary. Another subject treated briefly is that of "bumps" caused by air currents.

Ice formation on an airplane constitutes a serious danger. Ice is formed in a curious fashion. It seems to prefer wings, propeller blades and tail surfaces, rarely occurring elsewhere. Its accumulation is most rapid and it attains its greatest thickness near the leading edges of these surfaces. Its most favored camping ground is on the upper surface of the wing, just behind the leading edge. Here lies the root of the greatest danger. Wings are never intentionally given such a shape as this, for their resistance would be great and their lift very small. When ice forms on a wing, it takes on a form which leads to a loss of lift, an increase of resistance and a tendency to fall off into and remain in a spin. The only cure, once ice has formed, is to get rid of it, and one method is to install a rubber sheath for the leading edge of the surface; when inflated, it simply cracks the ice so that it is then carried away in small pieces by the wind.

Canadian Section Paper

Wednesday, April 17

The Modern Steel Motorcoach—*R. E. Fielder, vice-president, General Motors Yellow Coaches, Ltd.*

THE paper notes the trend of design of the city-type motorcoach, particularly the type suited to mass-transportation. It states that the last few years has seen the transportation features of the electric streetcar applied successfully to the motorcoach, first by the "Twin Coach," second by the "A.C.F. Metropolitan," and third by the "Transit Type" of the General Motors and the Mack companies.

The "Transit-Type" coach was designed in cooperation with the transportation and mechanical staffs of several of the largest users of city motorcoaches. Every effort was made to satisfy the passengers and the transportation experts; the lightest possible structure commensurate with the strongest, simplest and most economical mechanical unit, with due attention paid to its appearance, was sought.

The first fifteen 41-passenger "Transit" General Motors coaches have been in service at St. Louis for upward of three years, operating an average of 5000 miles per month. The features governing the design of the latest development of this "Transit" type, of which 100 are in the service of the Madison Avenue Co., New York City, are described in detail.

Canadian Section Paper

Wednesday, April 17

Outlook for High-Speed Diesel-Engine Application to Road-Transport Vehicles—*E. J. Cosford, president, Associated Equipment Co. of Canada, Ltd.*

AFTER reviewing the history of Diesel-engine development and comparing the Diesel-cycle with the Otto-cycle characteristics, the author cites statistics of Diesel-engine usage in Germany, England and the United States, and believes that the Diesel-engine industry is firmly established.

Diesel-engine design seems to be universally developed around three types: (*a*) the four-cycle type using an indirect fuel-injection method; (*b*) the four-cycle type using a direct fuel-injection method; and (*c*) the two-cycle type, which seems very promising.

The principal advantages of Diesel-engine usage in motor trucks are: Fuel economy, reduction of the fire hazard, and exceptionally good torque-characteristics during high-gear service. The most promising field is for trucks of 3-ton, or greater, capacity. Reasons are cited to prove that keen interest should be taken in Diesel-engine application.

Detroit Section Paper

Monday, April 22

Aircraft Structural Design and Its Influence on Other Engineering Design—*Carl F. Greene, Captain, Air Corps, Chief, Structures Unit, Material Division, Wright Field.*

THE subject is presented under the headings of aircraft structural requirements, evolution of structure, the necessity for testing, the engineering advantages of aircraft designers, the "doldrums" of aircraft design, new forms of old principles, beauty in design, and the future outlook for designing engineers.

The engineering demands made upon the designers of structures for aircraft are far more exacting from a standpoint of precision than those imposed upon the designers of any other class of engineering construction. These demands require that three widely opposed considerations be satisfied to the fullest extent possible; namely (*a*) maximum strength-weight characteristics, (*b*) outlines of aerodynamic fineness and efficiency, and (*c*) simplicity of construction, maintenance and repair. The aircraft structures in which these requirements or qualities find increasingly complete expression are beginning to display certain significant tendencies. It is observed that, almost universally, the principal structural components and the aerodynamic outlines of the fuselages or wings are now coming substantially into coincidence. In other words, the structural material is now so disposed as to form the exterior or aerodynamic outline of the aircraft.

The author states that, in looking over the designing field, it is possible to pick out many forms of engineering construction where application of the lessons learned in the development of strong, rigid wings and fuselages would greatly improve the quality and appearance of the object in question. He also draws some sound and truthful although possibly not new inferences, these being (*a*) that the principle of the efficiency of the peripheral distribution of structural material, so clearly brought out in aircraft, will find expression in many other forms of construction; (*b*) that the more engineering demands that are made on the designer, the better his product will be; and (*c*) that beauty resulting from efficient construction is the highest and most lasting form of beauty.

Don't forget the

S.A.E. THIRTIETH ANNIVERSARY

Summer Meeting

June 16-21, 1935

(See Insert)

Hartford Regional Meeting Paper

Friday, April 26

The Automatic Power and Mixture Control Developed by the Pratt & Whitney Aircraft Co.—*Guy E. Beardsley, Jr., project engineer, Pratt & Whitney Aircraft Co.*

THE paper presents a complete discussion of the engineering features of the Automatic Power and Mixture Control developed by the Pratt & Whitney Aircraft Co. It was used on the Hornet engines of the Pan American Sikorsky S-42 during its record flights from the United States to Hawaii and return, and now becomes available as optional equipment on the latest models of Pratt & Whitney engines.

The basic idea of accomplishing both a power limitation and a control of the mixture with one unit was evolved by the late Thorp Hiscock. He proposed, by throttling the air entering the carburetor, to maintain the density of the air entering the venturis equivalent to that at an altitude of 7000 ft. Thus the carburetor would virtually be held at 7000 ft. and would deliver, even though the airplane might be at sea level, a mixture of the same fuel-air ratio that it would normally deliver at 7000 ft.

Details of the development are given and the salient features are stated. From the reports available on general fuel consumptions it is apparent that some method of control is desirable. It is also highly desirable from a standpoint of engine reliability and durability that a means of controlling the horsepower output of supercharged engines as well as the fuel consumption be provided. The device described provides both these features with certain limitations.

Oregon Section Paper

Wednesday, May 8

The Future of Butane as a Motor Fuel—*George L. Holzapfel, president, general manager, Holzapfel Instrument Co.*

BUTANE is termed a very important link in the evolution of the motor fuel of the future because it has certain fundamentally important properties which give it a great advantage over gasoline. Its chief advantage is that it can be vaporized before admixture with the air necessary for combustion, while this is not easily achieved with the gasoline at present being sold.

Regarding butane carburetion, it is stated that carburetors which give the same air-fuel ratio over the whole range of speeds and loads may achieve fairly good results, but optimum results are achieved only by means of an economizer, similar in principle to a gasoline-carburetor economizer, the mechanism of which is explained.

Other points treated include spark setting, mixture strength the quantity of butane available, comparisons between butane and Diesel fuel, and an estimate of the cost of the equipment necessary for converting a vehicle to use butane. In conclusion, comments are made on the theory of operation and the method of constructing butane carburetors.

Washington Section Paper

Monday, May 6

Chemical Warfare—*Lieut. Comm. T. L. Schumacher, (CC) U.S.N.*

AFTER reviewing the history of the subject and clearing away some popular misconceptions of the effects of chemicals on human beings, the author cites the chemical agents which are satisfactory for war usage and classifies them according to their physiological effects. Among these are the "lacrimators," commonly called tear-gas; the "sternutators," or irritant smoke; the lung irritants; the incendiary types which burn furiously while throwing off molten sparks; and the "vessicant" type, of which one example is the so-called mustard gas.

Methods of usage of these agents and means of protection from their effects are described. The author states that increased effectiveness of chemical warfare, if any, probably will be due to improvement in the technique of using the existing chemicals, rather than the development of new chemical agents. Further, that perhaps the most important and far-reaching development in chemical attack will be the development of airplanes and the technique of delivering chemical attacks from them, such as the spraying of given areas with chemicals, probably of the mustard type.

Philadelphia Section Paper

Wednesday, May 8

Factors Governing Performance of Pistons and Piston Rings—*D. D. Robertson, chief engineer, Wilkening Mfg. Co.*

THE paper points out how the problems of decreasing oil-consumption and blowby and preventing piston slap are affected by different piston and piston-ring characteristics and some of the things that can be done toward solving them.

Improvements made in pistons—as to design, materials and construction—are cited. Problems concerning oil control are stated and means for solving them are set forth.

Interesting figures on piston-ring-wear tests are presented and the conclusion regarding them is that the wear of pistons, piston rings and cylinders, is due almost entirely to factors which, though usually present, are outside influences. These include abrasive material entering with the intake air, crankcase sludge, excessive choking, cold starting, and blowby. Further, that wear inside the cylinders cannot be eliminated without the use of improved air filters and oil filters and improved cold-starting conditions.

S. A. E.

PRODUCTION MEETING

September 18-19

(Two evening sessions)

Cleveland, Ohio **Hotel Statler**

The machine tool show of the National Machine Tool Builders Association will be held in Cleveland, September 11-21.

Metropolitan Section Paper

Monday, May 13

A Discussion of 1935 Cars—*Harold F. Blanchard, technical editor, Motor.*

THIS paper is largely limited to describing the new features which directly affect performance, although a few other items which seem of particular interest are included.

Before discussing the individual makes, one by one, the author calls attention to the lack of visibility in most of the new cars because roofs are low, windows are small, and pillars are large. The front corner of the body where the windshield pillar curves into the roof is a particularly bad blind-spot under some circumstances. For example, it may completely block out the view of an upgrade intersecting road into which the driver may be turning. The view at a level intersection may be similarly cut off if the road surface at the curb is depressed, as it frequently is. A few of the major specifications of the new cars are included and also a chart which gives piston displacement per mile per pound as an index of performance.

The Influence of Engine Oils on Aircraft-Engine Performance

By S. D. Heron
Ethyl Gasoline Corp.

OIL cooling of aircraft powerplants is increasingly difficult. The weight and drag of the oil coolers necessary with the present maximum "oil-in" temperature of 185 deg. fahr. (85 deg. cent.) are both decidedly objectionable. It appears possible to increase the "oil-in" temperature to about 220 deg. fahr. (104 deg. cent.) with oils which can be produced by the newer refining methods.

The use of an "oil-in" temperature of 220 deg. fahr. would render possible a material reduction in weight, size and drag of oil coolers in comparison with present practice. Oils suitable for use at 220 deg. fahr. "oil-in" temperature would not be likely to cause a material increase of engine-starting difficulty, as they would only be used in summer when the shearing resistance of the oil has slight influence on engine starting.

The approximate temperature cycle encountered by the oil in its passage through a modern aircraft-engine is discussed. The not generally realized importance of oil as a heat transfer agent in the high-duty aircraft-engine is briefly referred to. The lack of adequate knowledge of oil stability is dealt with.

It is stated that only extensive service tests of an unknown oil will, in the light of present knowledge, determine its stability. Further, that the stability, as determined by examination of the used oil and by engine effects, is usually similar but not always so, and that the latter is much the most important.

WITH increasing specific and total outputs in powerplant units, the problem of aircraft-engine oil-cooling is becoming more and more intense. The weight and drag of the oil coolers are both objectionable, the drag particularly so. The cost, either in added engine power or aerodynamic improvement, of any increment of speed has become high in modern aircraft of 200 m.p.h. or more top speed and any gain which may be obtained by modification of oil-cooling requirements would be worth a considerable increase in cost of oil. It appears that, by using improved lubricating oils which can be produced by new methods of refining, the "oil-in" temperatures of aircraft engines can be raised considerably with resultant reduction of size, weight and drag of oil coolers. Piston cooling in the modern high-output engine is to a large extent dependent on oil splash. With improved oils, it may be possible to both increase the oil cooling of the pistons and somewhat reduce the oil-cooler size as well.

In the past, 160 deg. fahr. (71 deg. cent.) has been regarded as an allowable maximum "oil-in" temperature and this has, with normal oils, gradually been increased to 185 deg. fahr. (85 deg. cent.) without objectionable effects on engine condition or serious increase of specific oil consumption.

The available data indicate that increase of "oil-in" temperature is sensibly without effect upon the production of solid gummy deposits such as produce piston-ring sticking, as long as the "oil-in" temperature is the only variable. If increase in "oil-in" temperature is accompanied by an increase of the quantity of oil fed to the pistons and bearings, the tendency toward stuck piston rings is usually reduced. In general, the accumulation of solid deposits such as occur in the piston-ring grooves limits the time between engine overhauls. In extreme cases, very short periods of engine overheating will cause piston-ring sticking with resulting piston and cylinder failure.

It appears to be beyond doubt that there are considerable variations in the stability of oils now in use for aircraft-engine lubrication or available for such use. No method except extensive test, either in service or on the test block, has yet been established which will more than approximately predict the behavior of aircraft engines operating on an unknown oil. Determination of the suitability of an oil for aircraft-engine use by full-scale tests appears to constitute the most difficult and uncertain engine test which the aircraft-engine manufacturer or operator has to undertake.

It is the author's opinion that the establishment of laboratory methods of determining the effective value of a fuel in an aircraft engine is a relatively simple problem in comparison with the determination of a suitable test for predicting the

[This paper was presented at the Annual Meeting of the Society, Detroit, Jan. 15, 1935.]

stability of oils in aircraft-engine or similar high-duty service.

The engine manufacturer and large-scale airline-operator can procure branded oils subsequent to prolonged service testing, and can thus avoid most of the difficulties due to use of oils of unknown stability. Even prolonged service testing is not always an adequate safeguard, as the stability of a branded product has been known to be inadvertently modified as a result of changes in refining methods, which showed the oil to be somewhat improved as regards the normal laboratory inspection, but diminished in stability in service. The small-scale operator who cannot afford service tests or the large-scale operator who must procure oil by bids against specification are continually in danger of serious service trouble due to procurement of oil by such methods. It is the author's opinion that no aircraft-engine oil-specification defines products of uniform stability, particularly as regards piston-ring sticking, since no proposed stability test has yet been proved to predict stability completely.

It appears possible that compounded oils may be extensively used in aircraft engines in the future and, should this occur, the need for test methods which will predict stability will become still greater than it is with purely mineral oils.

The general adoption of high-grade oil by aircraft-engine operators has been the result of costly service experience. The relatively unstable oils which gave fairly satisfactory results in water-cooled engines of low specific output, such as the Liberty, were productive of expensive service trouble when the air-cooled engine came into general use. Most of the modern air-cooled or high-temperature liquid-cooled engines of high specific output are more severe upon oil than were the earlier air-cooled engines, despite great improvements in cylinder and piston cooling and thus the greater benefit obtained by increased oil stability.

The Approximate Temperature Cycle of Oil in an Aircraft Engine.—Consideration of the approximate temperature conditions that an oil is exposed to in an aircraft engine from the time it enters the pressure pump until it is discharged by the scavenge pump appears to be of value in considering both "oil-in" temperature and stability. Oil may be assumed to enter the pressure pump of an air-cooled radial-engine at 185 deg. fahr., and to have increased in temperature by about 100 deg. fahr. as it leaves the bearings. Part of the oil leaving the bearings, particularly the connecting-rod big-end, is then thrown onto the cylinder bores, which will have a temperature of about 250 deg. fahr. at the base and about 350 deg. fahr. at the upper portion exposed to oil splash. Some of the oil will also be thrown onto the inside of the piston crowns, which reach temperatures as high as 650 deg. fahr. under the most severe conditions. The oil draining from the cylinder walls and pistons is known to do so at temperatures as high as 500 deg. fahr. under the most severe conditions. In radial engines, there is reason to believe that part of the oil draining from one cylinder is thrown into another cylinder rather than directly draining to the sump and thence to the scavenge pump. The throwing of oil from cylinder to cylinder would appear in part to explain the very high temperature of the oil draining from the cylinders. The oil draining from the cylinders to the crankpit then transfers heat to the crankcase, which is at a temperature of about 250 deg. fahr. The oil leaving the crankpit (radial engine) will, before admixture with cooler oil from other parts of the engine, have a temperature of 250 to 300 deg. fahr. The quantity of oil in contact with the cylinder bores and piston interiors is relatively small at any one time, and thus the oil may be expected to be nearly in thermal equilibrium with the surfaces with which it is in contact. Thus, it is unlikely that its temperature just prior to coming into contact with piston and cylinder surfaces will significantly influence the final temperature attained. This latter statement is, of course, only true for a limited temperature range, and if the oil as it left the bearings and was thrown to the pistons attained a temperature of the order of 500 deg. fahr., increase of piston, cylinder and drained-oil temperature could be expected.

The important function of oil as a heat-transfer agent in an aircraft engine is not always realized. The data indicate that a great deal of heat which never appears in the final balance of heat given to the oil is transferred by oil from the piston to the cylinder and from cylinder and piston to the crankcase, and so on. Such heat transfer is exclusive of that conducted across the film between the piston and the cylinder wall.

"Oil-in" Temperature in Aircraft and its Relation to Oil Consumption.—Oil-temperature regulation has been a problem in aircraft since 1916 if not longer. In the main, the objection to high oil temperature at the intake of the pressure pump has been due to the increase of consumption as the intake temperature rose. Reduced bearing life with very high "oil-in" temperature appears to have been experienced in some cases. With "oil-in" temperatures of approximately 220 deg. fahr. (104 deg. cent.) and the oil leaving the bearings at about 320 deg. fahr. (160 deg. cent.) in conjunction with bearings with thick and badly bonded babbitt facings, it is not surprising that bearing trouble should have been experienced in production engines built during the war.

In the conventional engine-lubricating system in which an attempt is made to maintain constant oil pressure, increase of "oil-in" temperature results in more oil passing the bearings and less going by the relief valve. When more oil passes the bearings, a greater amount is thrown to the cylinder walls. It is the increasing amount thrown to the cylinder walls as the "oil-in" temperature rises which appears to be the major cause of increased consumption.

In some cases, however, high "oil-in" temperature is the result of high atmospheric temperature which not only affects oil coolers, tanks, and the like but, in the case of air-cooled engines, causes an increase of cylinder-wall temperature. Under these circumstances, increase of oil consumption appears to be due to both a greater amount thrown to the cylinder walls and reduced viscosity of the film on the walls.

The amount of oil thrown to the cylinder walls in most engines is controlled by either the viscosity at the pump intake or by the mean viscosity in the bearings, and it is more likely that the latter is the true controlling factor. The viscosity at the pump intake of an average summer oil (120 sec. S.U.V. at 210 deg. fahr.) is about 300 sec. S.U.V. at 160 deg. fahr. and about 180 sec. at 185 deg. fahr. Some tests at full throttle with an air-cooled engine at normal summer cylinder temperature showed that an oil of 55 sec. S.U.V. at 210 deg. fahr. (330 sec. S.U.V. at 100 deg. fahr.) gave excessive oil consumption at a viscosity of about 300 sec. S.U.V. at the pump intake. Increase of temperature of the oil film in the bearings above the "oil-in" temperature on the basis of any existing data would not account for the wide disparity in consumption between the 120 and 55-sec. oils and cylinder-wall viscosity would thus appear to be the controlling factor in this case.

Other tests at cruising power (about 60 per cent full throttle) have shown, however, that both air and liquid-cooled engines can be operated on the test block and in flight with substantially normal oil consumption under winter conditions

if an oil of 55 sec. S.U.V. at 210 deg. fahr. is used with a viscosity at the pump intake of about 180 sec. S.U.V. It is possible with some engines to use an oil of 55 sec. S.U.V. at 210 deg. fahr. with a viscosity as low as 90 sec. S.U.V. at the pump intake without abnormal oil consumption at cruising power, and cylinder-wall temperatures corresponding to winter flight conditions.

It appears that the question of increased "oil-in" temperature should be considered on a basis of constant viscosity at the pressure-pump intake, as this is the least favorable condition to the case for higher intake temperatures.

Oil Cooling.—Since the mean temperature difference between the oil in the cooler and the available cooling air in summer is, under the worst conditions, less than 100 deg. fahr., a permissible increase of even 20 deg. fahr. in "oil-in" temperature means a considerable reduction in oil-cooler duty. With increase of "oil-in" temperature, the proportion of cooling due to oil tanks, oil lines and the like, becomes greater and the amount of heat to be dissipated by the coolers is diminished even more than would be indicated by the increase in mean temperature difference between the atmosphere and the oil in the coolers.

If viscosity at 210 deg. fahr. is increased to about 200 sec. S.U.V. and the viscosity index increased to about 107, it would appear that "oil-in" temperatures of the order of 220 deg. fahr. should be possible with engines that now operate satisfactorily at 185 deg. fahr. "oil-in" temperature with normal 120 sec. summer oil. In Fig. 1 the viscosity-temperature characteristics of such a 200-sec. oil produced from Pennsylvania crude by solvent extraction are shown on an A.S.T.M. viscosity-temperature chart. Fig. 1 also shows the viscosity-temperature characteristics of the average 120-sec. oil used by the U. S. Army Air Corps and of the 55-sec. oil used in the tests of light oil which are discussed above. Fig. 1 shows that the viscosity of the 200-sec. oil at 217 deg. fahr. is equal to that of the 120-sec. oil at 185 deg. fahr. In cases where high cylinder-wall viscosity is a factor in keeping oil consumption down, the 200-sec. oil should have considerable advantage over the 120-sec. grade.

With the average 120-sec. oil shown in Fig. 1, starting is possible but not easy at 30 deg. fahr. or approximately 50,000 sec. S.U.V. With the 120-sec. oil, starting is usually fairly easy at 45 deg. fahr. or 20,000 sec. S.U.V. as far as resistance to shear of the oil is concerned. In Fig. 1 it can be seen that the 200-sec. oil has viscosities of 50,000 and 20,000 sec. at approximately 40 and 57 deg. fahr. respectively. Thus, for approximately equal ease of starting, the engine temperature must be 10 to 12 deg. fahr. higher than with the 120-sec. oil, which does not appear to be a serious objection as such a 200-sec. oil would only be used in summer when oil cooling is most difficult.

Single-cylinder tests of the 200-sec. oil shown in Fig. 1 at elevated "oil-in" temperatures have shown the engine performance and oil stability to be just as satisfactory as that obtained with normal summer oil at normal "oil-in" temperature. In these tests, the amount of oil fed to the bearings was

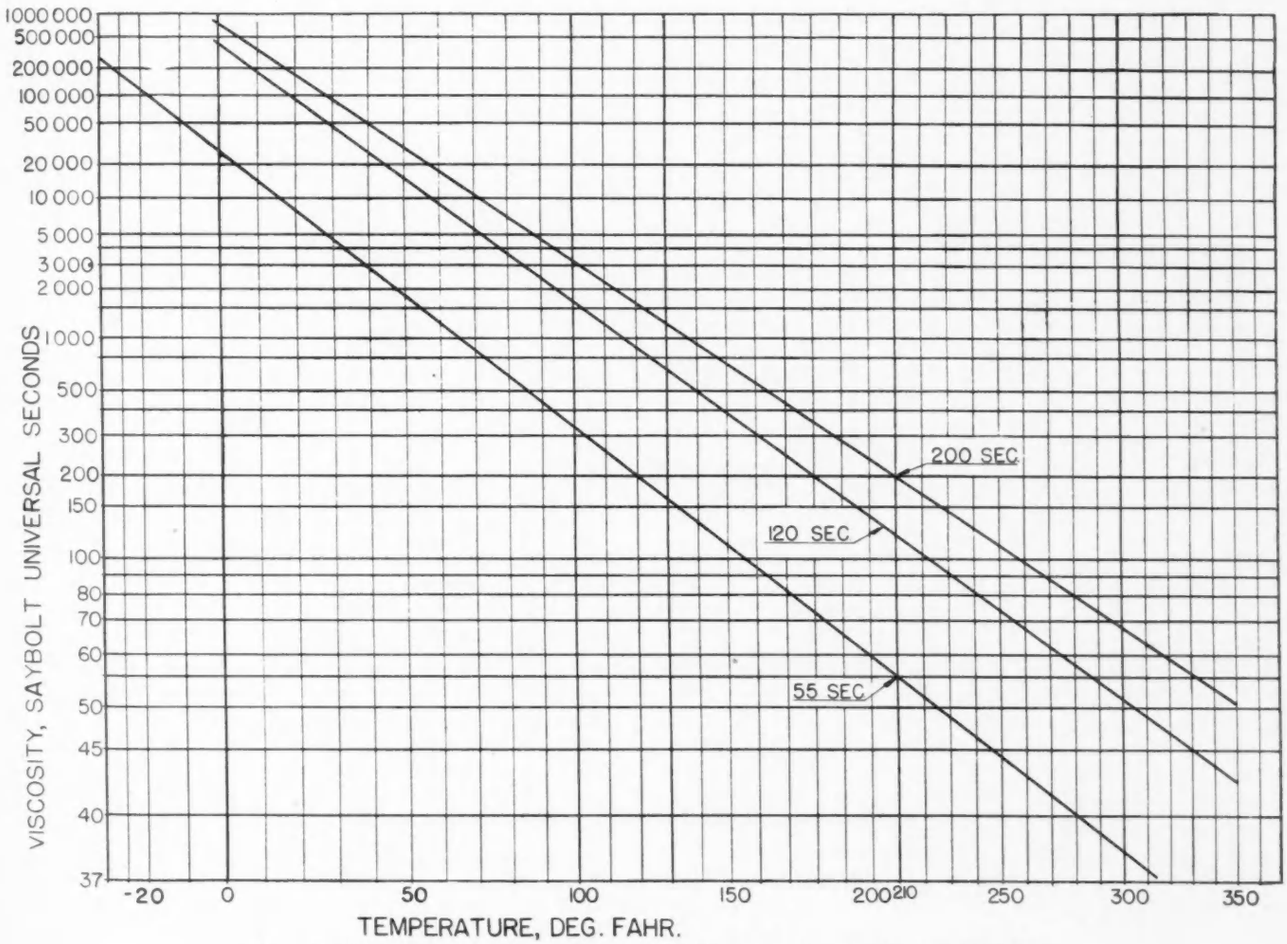


Fig. 1—Viscosity-Temperature Chart (A.S.T.M. Tentative Standard D-341-32T)

independent of oil temperature or viscosity. Single-cylinder tests are not always reliable, and multi-cylinder-engine data are unfortunately lacking so far on the 200-sec. oil.

The one 200-sec. oil shown in Fig. 1 has been used to illustrate the case for high "oil-in" temperatures because it represents the only type on which single-cylinder performance is available to the author. Other oils of the same viscosity at 210 deg. fahr. and of higher viscosity-index are available, but data on their engine performance at high "oil-in" and cylinder temperatures are not available to the author.

Increase of viscosity index with oil of any viscosity (at 210 deg. fahr.) appears to be desirable for aircraft use on account of the resultant improvement in starting and allowable increase of "oil-in" temperature. Where aircraft are operating over a route including semi-arctic and sub-tropical conditions —for example, from the Canadian border to the Gulf of Mexico—the use of an oil with extremely high viscosity-index may produce reasonably satisfactory operation under conditions where normal oils would not be satisfactory. Increase of viscosity index above present specifications will reduce the number of grades of oil necessary for operation under the widest variation in atmospheric temperature. At present, the Air Corps requires five grades of oil for operation between —20 deg. fahr. and 110 deg. fahr.

While high "oil-in" temperature may have been productive of bearing trouble with babbitt bearings of poor design and manufacture, it would appear that the lead-bronze bearings used in modern aircraft engines should not be appreciably affected by oil temperatures of the order proposed.

Some Consideration of Stability.—(*A*) *Engine effects.*—The problem of lubricating-oil stability may be viewed from two standpoints; first, what the engine does to the oil and, second, what the oil does to the engine. These effects are usually similar but are by no means always so. The oil technologist in the past has largely considered the matter from his own special angle of the change in physical and chemical properties of his oil. It would appear that change in the oil properties is of much less importance as regards overall costs of engine operation and overhaul than are the oil effects on the engine.

Instability of oil has three primary effects on engine operation, of which only the first two are usually of serious significance. These are as follows:

(1) The deposition of solid gummy matter in piston-ring grooves, on the bearing portions of the piston skirts, on the interior of the piston crowns and on exhaust-valve stems. Deposits in the piston-ring grooves, which may vary from soft, sticky consistency to hard, brittle material, are of greatest significance as they eventually lead to stuck piston rings which, in turn, cause seized or burnt pistons and stoppage of the engine.

(2) The formation of finely divided solid filterable material in partial suspension in the oil. Accumulations of solid deposits on the interior of the pistons which intermittently break off and fall into the crankcase appear to be a contributing source. Such solid material, if in large-enough particles, will either settle in the crankcase or choke the suction screens of the scavenge pumps. The finer material which is carried in the moving oil-stream tends to choke the pressure oil-filters and, if passing the latter, may be centrifuged out in the crankshaft journals or pins. Centrifuging out of finely divided matter in the crankpins or journals or in the small oil passages of the connecting-rod assemblies is at times the cause of connecting-rod failure. While deposition of sludge is not often a major trouble with present engines and oils, it does occur, however, to a significant extent, with some oils which are satisfactory as regards piston-ring sticking, and its prevention should be given consideration.

(3) Distillation of the lighter fractions, polymerization or oxidation to such an extent that the viscosity increases seriously. When this occurs the flow of oil through the engine at normal operating temperature may be reduced, possibly with serious effects. In addition, starting may become difficult and the flow of oil through the engine during warming up may be so reduced as to cause piston scuffing in cold weather. Serious increase of viscosity in service is not in general encountered when the oil is changed with reasonable frequency.

(*B*) *Determination of Stability in Engines.*—In attempting to determine the relative stability of oils in full-scale engines a variety of difficulties are encountered and some of these are as follows:

(1) The amount of oil thrown to the pistons has a pronounced effect on the rate at which solid deposits accumulate in the ring grooves and on the piston interiors. Control of the oil thrown to the pistons is usually attempted by close regulation of "oil-in" temperature. This method of control does not appear to be sufficiently close, and the use of a pump delivering a fixed quantity of oil to the bearings independent of oil temperature or viscosity would seem preferable for tests carried out on the ground.

(2) Specific fuel consumption has a marked effect on cylinder and piston temperature. There is some reason to believe that change of piston temperature as a result of change of specific fuel consumption is not always reflected in change of cylinder temperature.

(3) Cylinder temperature has, of course, pronounced effects in decomposing oil. Increase of cylinder temperature often causes an increase in the amount of oil passing the piston rings. An increase in the amount of oil passing the rings probably in part offsets the objectionable effects due to the temperature increase alone. Cylinder-wall temperature obviously requires close control, and it appears that it should not be regulated by means of varying the specific fuel consumption.

(4) Quantitative determination of piston deposits and accumulations of sludge in the crankcase, crankshaft, oil tanks, oil lines and the like, is tedious and difficult.

Stability tests in small single-cylinder engines with all the known variables rigidly controlled offer an attractive alternative to the difficulties of full-scale testing.

The Materiel Division of the U. S. Army Air Corps has carried out several hundred hours of full-scale testing of oils in the last five years. The full-scale work has been paralleled by several thousands of hours of running on fuel-test engines.

After considerable work on single-cylinder test-methods, a fair degree of reproducibility was secured and the relative ratings as regards piston-ring sticking, obtained on a group of very diverse oils, were thought to be of considerable value. However, it was then decided to vary conditions by changing the piston material from cast iron to aluminum, with all other conditions held constant. As a result of this change, three oils of very diverse type, which had considerable differences in stability with the cast-iron piston, were, with the aluminum piston, given a different order of relative stability. As a result of these tests, it was felt that single-cylinder results could not be regarded as a reliable index until many more full-scale data were obtained for further correlation with the single-cylinder ratings.

However, whatever may be the defects of single-cylinder tests, they have been productive of a great amount of data both negative and positive, and are undoubtedly much closer

to full-scale results than most of the oil testing in glassware which has been carried out in the past.

While the problem of determination of stability appears to be one of great difficulty, there is every reason to believe that it can be solved by energetic attack on a fairly large scale. To reach a solution in which the engine operator can have confidence, a considerable amount of full-scale testing will be necessary; otherwise, single-cylinder tests or oxidation methods will constitute just so much more laboratory data of unknown relation to the full-scale engine.

Conclusion

The necessity for the establishment of reliable laboratory methods of determining the stability of oils for aircraft-engine use appears to be of great importance at present. The aircraft-engine manufacturer and operator are subjecting engines to increasingly high duty, and are requiring better oils for this purpose. New methods of refining are rendering possible the production of oils which are greatly improved in a variety of their qualities; but, in the present state of our knowledge, the use of such oils in aircraft-engine service involves some uncertainty as regards stability.

This paper is almost entirely based on data obtained by the author during service with the Materiel Division, U. S. Army Air Corps. The interpretation put on the data is that of the author and is not necessarily related to the views of the Air Corps. The author wishes to thank the Air Corps for permission to draw upon data in its possession.

Measurement of Airplane Landing Speed

VARIOUS methods of measuring landing speed have been used in trying to develop an accurate one. The one used by most flight test agencies was to calibrate the airspeed indicator to as low a speed as possible over the speed course—usually down to about 20 m.p.h. above stalling speed—and then extend the curve down into the stalling region along the same general curve as was found at higher speeds. The test pilot would bring the airplane in to a landing and an observer would watch the airspeed indicator and take the reading as the wheels touched the ground. The airspeed indication was then corrected by use of the calibration curve and this value was used as the landing speed.

To get more accuracy various methods were devised of counting the revolutions of the wheels for a given number of seconds after they touched the ground and calculating the speed. These methods proved inaccurate because of slippage of the tire on the runway when contact is first made. Just before the wheels touch the ground they are not turning, so their inertia plus the friction of the wheel bearings added to brakes, which possibly drag, make it an appreciable amount of time after the wheels touch the ground before their rate of revolution corresponds to the forward speed of the airplane.

The method which only recently has been successfully developed for accurately measuring the landing speed of Boeing airplanes consists of a 35 mm. moving picture camera, a large grid and an anemometer. The camera must be carefully calibrated to obtain the exact number of exposures that it makes per second. This was done very accurately by photographing the pendulum of a large grandfather clock for several seconds. Photographing the second hand of an electric clock did not work so well, as the motion of the hand is so small that with a camera taking 15 pictures per second, the hand would appear to be in the same place for two or three exposures. The pendulum has lots of motion and it was possible to calibrate the camera down to hundredths of a picture per second. Our camera was rated at 16 and it was calibrated at 15.02 pictures per second.

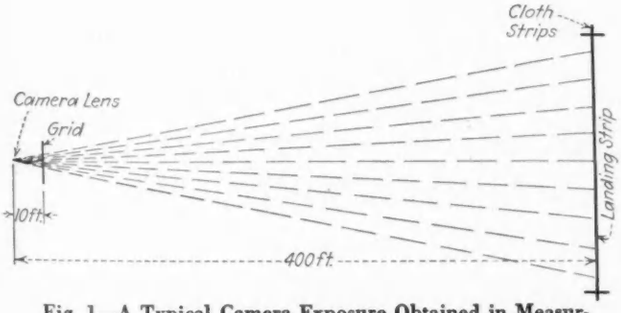


Fig. 1—A Typical Camera Exposure Obtained in Measuring Airplane Landing-Speed

The camera is set up at the edge of the airport on a tripod. The grid is placed exactly 10 ft. in front of the center of the camera lens, and out on the runway 400 ft. in front of the lens strips of cloth are laid on the field to indicate to the pilot where the airplane must land.

As the airplane comes in for the landing, the camera is turned on just before the wheels touch the ground and is left running until the airplane has passed out of the range of the camera. At the time of each landing the wind speed is measured with the anemometer and the spot on the landing strip where the wheels touch the ground is jotted down in a note book. The wires on the grid through which the photographs are made are spaced 6 in. apart and the distance out on the landing strip, which each wire represents, is equal to the wire spacing on the grid multiplied by the distance from the camera to the landing strip divided by the distance from the camera to the grid. Therefore, each wire on the grid represents (0.5) (40)/10 = 20 ft. on the landing strip.

A typical exposure is shown in Fig. 1. There will be 20 to 30 exposures while the airplane is crossing the full width of the grid. Each exposure shows the airplane has traveled forward a certain number of feet, and knowing the number of exposures per second it is a simple matter to calculate the ground speed of the airplane just as the wheels touch the runway.

Ground speed (ft. per sec.) = feet traveled per exposure times the number of exposures per second, or in miles per hour = above, divided by 1.47.

The landing speed, which we are trying to determine, is really air speed, as the landing may have been made against a wind. The wind speed which was measured at the time of the landing is added to the ground speed.

Landing speed (m.p.h.) = ground speed + wind speed against which landing was made.

This method of measuring landing speed has proved to give consistent and accurate results.

Excerpt from paper entitled "The Measurement of Landing Speed and other Flight Test Procedure" presented at the Northwest Section Meeting, Seattle, Dec. 14, 1934, by Ralph L. Cram, research engineer, Boeing Aircraft Co.

Progress Report of Volunteer Group for C. I. Fuel Research

By T. B. Rendel
Shell Petroleum Corp.

DURING the last two years there has been a very marked tendency toward increasing the speed of Diesel engines, so much so that the Diesel engine is now able to compete with the gasoline engine for road-transport work. This is undoubtedly a remarkable achievement. At the same time, these newer types of engines are somewhat more sensitive to fuel changes than their more elderly cousins, and this sensitivity has resulted in the last two years in an intensive research campaign on fuel quality, as a result of which the importance of ignition quality of the fuel has been brought out. This was first recognized by H. Ricardo in England and later developed and standardized by Messrs. Boerlage and Broeze[1] of the Royal Dutch Shell in Holland, and by Messrs. Pope and Murdock[2] of the Waukesha Motor Co. in this country. As a result of this research, and work by other investigators on this subject, it soon became clear that some coordination was needed in order to develop a standard method of rating Diesel fuels for ignition quality.

Formation of Volunteer Committee

Some coordination was attempted by a joint committee of the Society of Automotive Engineers and the American Society of Mechanical Engineers and an ambitious program of research drawn up in which the importance of ignition quality and viscosity was stressed. However, it was found impossible to obtain sufficient funds to carry out such a program of research and, at the end of 1933, a small group of men known as the Volunteer Group for C. I. Fuel Research banded together in order to carry out some cooperative experiments on the most promising methods of measuring ignition quality. It was not the intention of the committee to encroach upon any work now being carried out by recognized committees of the various societies such as the A.S.M.E., the A.S.T.M. and the S.A.E. However, it was thought that the delays caused by difficulties that would be encountered in obtaining necessary funds to carry out any large program of Diesel-fuel research could, to some extent, be minimized by a small group of men carrying out a cooperative program of work in their own laboratories which would hasten preliminary work on important phases of cooperative Diesel-fuel research.

A list of the members of this committee is as follows:

T. B. Rendel, Chairman	Shell Petroleum Corp.
C. H. Baxley, Secretary	Sinclair Refining Co.
Dr. A. E. Becker	Standard Oil Development Co.
J. F. T. Berliner	E. I. duPont de Nemours
T. A. Boyd	General Motors Corp.
H. F. Huf	Atlantic Refining Co.
Neil MacCoull	Texas Co.
C. H. Schlesman	Socony Vacuum Corp.
W. H. Hubner	Universal Oil Products Co.
L. C. Lichty	Yale University
H. L. Horning	Waukesha Motor Co.
J. R. MacGregor	Standard Oil Co. of California
D. P. Barnard	Standard Oil Co. of Indiana
H. K. Cummings	Bureau of Standards
W. G. Ainsley	Sinclair Refining Co.
C. F. Taylor	Massachusetts Institute of Technology

Preliminary Investigations

When the committee was formed, there were in existence two methods of measuring ignition quality which seemed to be the most promising, both involving the use of actual engines rather than tests in some form of "bomb." The method best known in this country was that proposed by the Waukesha Motor Co., in which use was made of a modified C.F.R. engine to determine the critical compression ratio at which the fuel would fire within 3 sec. after being injected into the cylinder when the engine was externally driven at 600 r.p.m., intake air being maintained at 100 deg. fahr. and the jacket at 212 deg. fahr. The other promising method, that proposed by Messrs. Boerlage and Broeze, involved the measurement of the actual ignition delay by means of a Maihak pressure-time indicator in a large slow-speed solid-injection engine at a compression pressure of 450 lb. per sq. in. The engine used was one made by Messrs. Thomassen and was run at one-quarter load with a jacket temperature of 165 deg. fahr. The del. period of the fuel under test was compared with the dela obtained on mixtures of cetene and alpha methylnaphthalene, and the percentage of cetene in this mixture which gave the same delay as the fuel under test was called the cetene number. The cetene number of Diesel fuel was thus analogous to the octane number of gasoline.

Early experiments with the Waukesha method brought out the fact that the engine was not very satisfactory for some

[This paper was presented at the Annual Meeting of the Society, Detroit, Jan. 16, 1935.]

[1] See S.A.E. JOURNAL, July, 1932, p. 283; "Ignition Quality of Diesel Fuels as Expressed in Cetene Numbers," by G. D. Boerlage and J. J. Broeze.

[2] See S.A.E. JOURNAL, March, 1932, p. 136; "Compression-Ignition Characteristics of Injection-Engine Fuels," by A. W. Pope, Jr., and J. A. Murdock.

Summary

THE tendency toward increasing the speeds of Diesel engines has caused them to become more sensitive to fuels and research on the latter has brought out the importance of ignition quality; however, some coordination has been needed for this research in order to develop a standard ignition-quality test. In order to escape the difficulties that were hampering the activities of a joint research committee of the S.A.E. and A.S.M.E., a Volunteer Group for C.I. Fuel Research took up the study of fuels in their own laboratories.

Two test methods had been proposed before the formation of this Volunteer Group, the critical-compression-ratio test and the ignition-delay test. The former gave considerable variation; however, the converted C.F.R. engine could not be used for the latter method because of unsteady operation, so a new cylinder was designed. Experiments with the new cylinder, using the delay-measuring method, are in progress. The ignition delay is indicated on the knockmeter, operated by the bouncing pin, a matching test being used similar to the octane-number test for gasoline. The result is expressed in the equivalent mixture of reference fuels, cetene and alpha methylnaphthalene, called the cetene number. The delay method appears to be less rapid than the critical-compression-ratio method, but more accurate.

The program of the Volunteer Group includes improvements in the test procedure and correlation with service engines. Other methods of test will be investigated along with the engine method.

About ten of the new engines are in operation, the laboratories mostly familiarizing themselves with the new equipment. The main difficulty is in obtaining steady injection, though no major difficulties appear to be in sight.

types of work; for example, tests for measuring ignition delay while running, since it did not maintain its condition for any great length of time due to poor combustion and the results, consequently, were not very reproducible. A preliminary series of tests run by the Volunteer Group using the original Waukesha equipment and method of tests and rating ten fuels in seven different engines showed a grand average deviation from the mean result of ± 0.35 of a ratio with maximum variations ranging from $+1.27$ ratio to -0.96. While this is not a condemnation of the engine and method of test, it does indicate that a much greater degree of detailed standardization is required before close reproducibility between different engines can be obtained.

New-Type Cylinder-Design

However, the need for better combustion had been previously recognized by the Waukesha Motor Co. and by Messrs Boerlage and Broeze and, at the beginning of 1933, it was decided by both investigators to redesign the entire cylinder and cylinder head of the C.F.R. engine in the light of the best available knowledge of combustion-chamber design in order to obtain steadier operation and cleaner combustion. Figs. 1 and 2 are sectional drawings of the new head and cylinder, showing the general design features and mechanism for varying the volume of the combustion space. The standard C.F.R. piston is used and the clearance adjusted to 0.022 in., leaving practically no space between the piston and the surface of the head. All of the air taken in on the suction stroke is thus compressed into the horizontal cylindrical combustion chamber.

The passage between the cylinder proper and the combustion chamber is so located that the incoming air is directed tangentially to the chamber, along the base of the injector end of it, producing a very high controlled turbulence. Fuel is injected into the end of the cylindrical combustion chamber, horizontally, parallel to the axis, but it will be noted that the injector is not placed centrally in the combustion chamber. This is to insure that the injector tip shall be well in the whirling airstream and thus be kept free from carbon accumulation. The volume of the separate combustion chamber is varied by means of a movable compression plug, the position of which is adjusted by means of a hand wheel on a threaded shaft. In order to prevent leakage of gases past this plug, an expanding mechanism has been provided by which the end of the movable-plug mechanism can be locked into position by a turn of a locking handle.

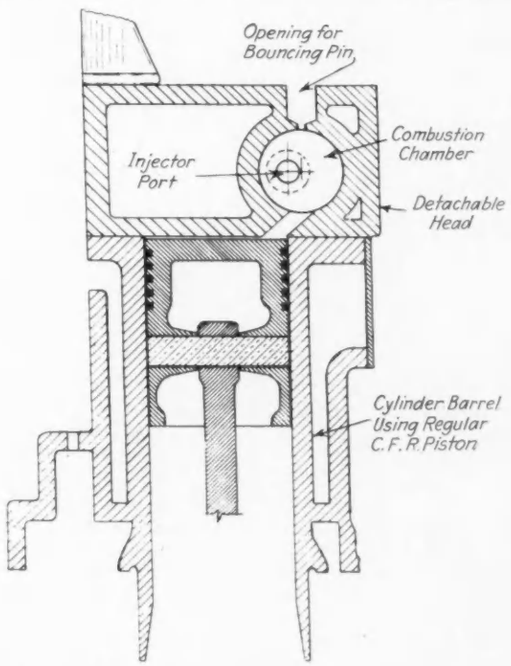


Fig. 1—Section of the New Diesel Cylinder for the C.F.R. Engine

It is possible to use both the critical-compression-ratio method of rating fuels described by Messrs. Pope and Murdock and also, in conjunction with a modified type of bouncing pin, the delay method suggested by Messrs. Boerlage and Broeze, and to obtain measurements of the ignition quality of a Diesel fuel with reasonable accuracy and with a minimum amount of engine maintenance.

When operating according to the delay method, the method of test is very similar to and employs the main advantages of the octane-number antiknock-test for gasoline. Briefly, the test method utilizes a bouncing pin that has been rebuilt to break instead of make an electrical circuit when the pin is "bounced" upward by the shock of combustion. It is thus used to stop a current that is started by a cam on the end of the fuel-pump shaft, timed to make contact at some instant in a definite relation to the time of injection. The total current that flows from the time the fuel is injected until the time combustion begins, that is, the time when the pin is "bounced", is a measure of the delay period. By allowing this current to flow through a regular knockmeter similar to that used on the gasoline knock-testing engine, it is possible to find a mixture of reference fuels with the same knockmeter reading and, hence, delay period, as the fuel under test. By using mixtures of two standard fuels such as cetene and alpha methylnaphthalene (or suitably calibrated secondary reference fuels) it is possible to obtain the ignition quality of the fuel expressed in relative terms, such as cetene number. Fig. 3 shows a sketch of the type of bouncing-pin circuit used in this test.

In addition to this hook-up, an optical indicating device is also provided for the purpose of determining the exact point at which the pin begins to bounce. Fig. 4 shows diagrammatically how this is accomplished. A small prism *A* is mounted on the contact arm of the special bouncing pin such that it moves through a small arc when the pin is bounced by the shock of combustion. The beam from a small light mounted on the flywheel is reflected by prism *B* on to prism *A* so that, when the flywheel is revolving with the pin at rest, the reflected light appears, on looking into prism *A*, as a continuous line of light. Then, with the engine firing, a definite deflection of the line of light occurs when the pin is bounced by the shock of combustion; the point of this deflection being noted on a scale, graduated in degrees of crank angle, which is fixed above the flywheel. A sliding pointer, that can be moved along the scale, is provided to facilitate the determination of the point at which the deflection of the line in degrees of crank angle occurs.

Program of Volunteer Committee

Using this modified type of high turbulence C.F.R. Diesel engine and equipment, the Committee has begun a program which has as its objective the perfecting of a method for measuring the ignition quality of Diesel fuel with the expectation that it can be later recommended for universal adoption and submitted to the A.S.T.M. and A.S.A. as a standard method. The experimental work naturally falls into two main divisions, the first division being subdivided into three sections:

A-1.—Perfecting the Test Engine and Technique.—Improvements for convenience, simplicity and reproducibility will have to be worked out and the apparatus for measuring the relative delay period and critical compression ratio of different fuels perfected. After preliminary tests by individual members to familiarize themselves with the apparatus, cooperative experiments will be run with a view to ascertaining the reproducibility of different engines obtained by the various methods.

A-2.—Suitable Scale for Expressing Ignition Quality.—An engine test will need some standard reference scale. The use of some standard fuels such as cetene and alpha methylnaphthalene will be tried as a means of expressing relative ignition quality.

A-3.—Effect of Various Engine Factors on Relative Rating of Different Fuels.—In order to obtain information necessary for determining the engine conditions which will give best reproducibility and for working out correlation experiments with service engines, the effect of certain engine factors on the ignition quality ratings should be worked out:

(1) Effect of air temperature
(2) Effect of fuel temperature
(3) Effect of fuel quantity, both total and per injection
(4) Effect of air turbulence
(5) Effect of carbon deposits
(6) When operating as a motored engine the effect of the number of successive injections (down to one individual injection) prior to firing.

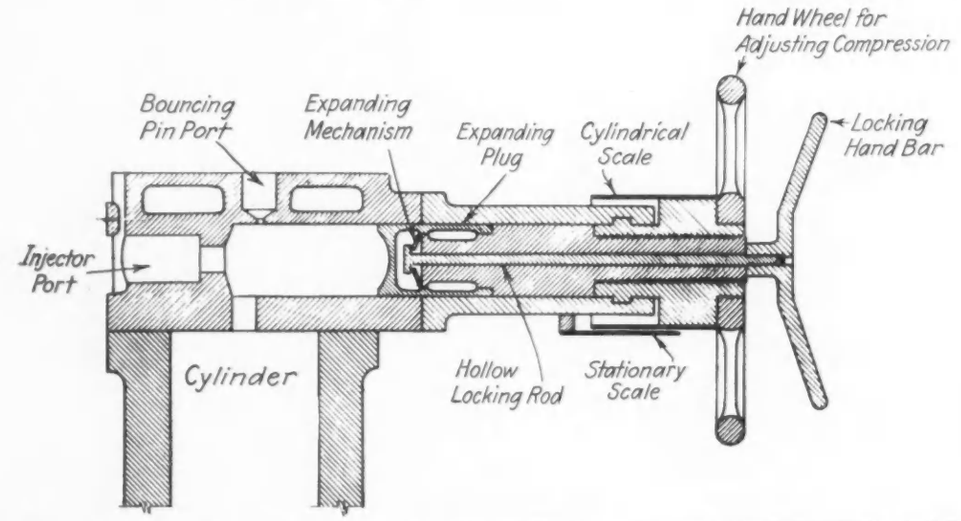


Fig. 2—Section Through the Cylinder Head Showing the Mechanism for Varying the Volume of the Combustion Chamber

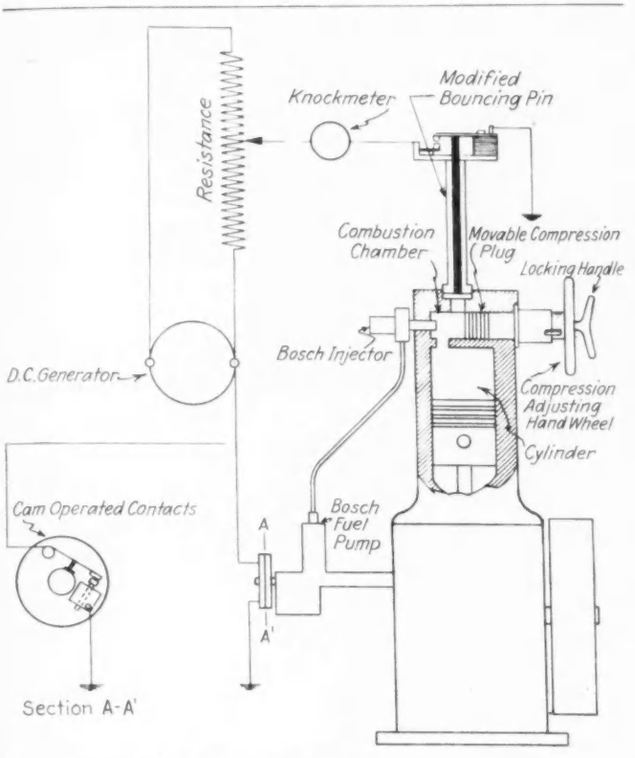


Fig. 3—Modified Bouncing-Pin Circuit for Delay Measurements

A-4.—Physical and Chemical Methods of Rating.—Other methods of rating fuels will be considered, such as the Diesel Index developed by Drs. A. E. Becker and H. G. M. Fischer of the Standard Oil Development Co., or the method of measuring paraffineity by a modified viscosity-gravity constant developed by Messrs. Moore and Kaye of the Union Oil Co. Fortunately, these methods can be investigated along with the engine methods without materially increasing the work involved.

B.—Field Testing and Correlating Service Results with Laboratory Tests.—In carrying out the work outlined above the Committee is already doing and will have to do some informal correlation work with service engines. It is recognized, however, that an extensive and detailed work program will need to be carried out later. Such a program will involve a large number of tests with both large and small engines and may eventually involve the cooperation of a larger group of laboratories. It was recommended, therefore, that while fully recognizing the need for such work, the formal investigation of this problem should be considered separately until such a time as the necessary work on the first phase shall have been investigated more fully, and it is hoped that this knowledge, coupled with the information gained under heading *A-2*, will enable the Committee to arrive at a set of laboratory engine methods which will correlate reasonably well with actual service conditions.

Work Carried Out to Date

Already a fair amount of work has been done under Division *A-1* by the Committee, and a few of the members have also carried out a number of experiments under *A-2*. Approximately ten of the new-type engines are now in operation in the laboratories of the members of the Volunteer Group, and a tentative procedure for running the engine according to the delay method has been worked out, though as yet there is not enough experience with this procedure to justify even a tentative adoption.

A few minor troubles have shown up such as the difficulty of obtaining a really steady fuel injection with different-viscosity fuels, and the determination of a suitable method of setting the bouncing pin still requires further investigation. However, no major difficulties appear to be in sight and arrangements are being made with the Waukesha Motor Co. for one of their engineers to visit the laboratories of the various members to settle small matters of standardizing the equipment prior to running the first series of cooperative tests employing the new engine. At present, the laboratories are each using their own individual procedure in order to get necessary experience of the general operation of the engine. In some tests run in the author's laboratory, as a result of about eighteen months' experience with this engine, we have found that the delay method of testing is not as rapid as the method employing the critical compression ratio but is somewhat more accurate. Average deviations in terms of cetene numbers as a result of twenty-five tests were ± 0.8, the maximum variation being ± 2.2. This compares fairly satisfactorily with the octane-number tests of gasoline although, of course, it should be remembered here that these reproducibility tests involve only one engine and one operator.

In regard to the use of standard fuels, the two fuels that seem to be the most widely adopted at the moment are cetene, which will shortly be available from duPont de Nemours, and alpha methylnaphthalene, which has been obtained from the Reilly Chemical Co., Indianapolis.

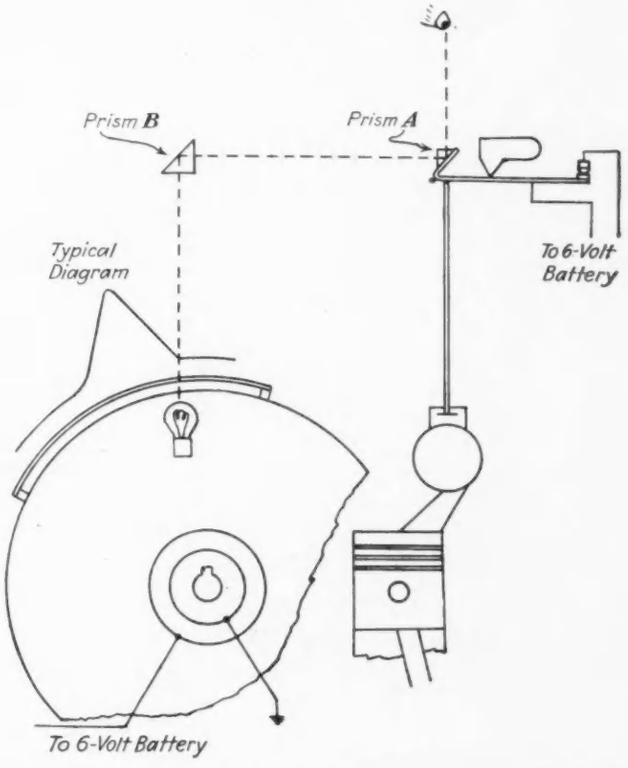


Fig. 4—Optical Indicating Device for Determining the Exact Point at Which the Bouncing Pin Begins to Bounce

A Rational Basis for Comparing Diesel-Engine Performances

By E. S. Dennison
Westinghouse Electric & Mfg. Co.

THE paper describes a procedure for analyzing the performance of an internal-combustion engine. It is first shown that the characteristics of ideal cycles can be conveniently represented with the help of a fictitious "fuel mean pressure" which is proportional to the useful heat input. The diagram so obtained is used to represent certain ideal Otto and Diesel cycles. It is pointed out that actual performance can be similarly expressed.

A simple correction for the variation of atmospheric conditions is then introduced. Examples from tests are used to show that this correction is in accordance with actual experience. The final form of the proposed diagram embodies the correction.

It is then shown that the performance of a cylinder as it appears in this diagram is a measure of the success of the designer in dealing with factors lying within his control, as distinguished from those arising from the conditions of operation. Therefore, a comparison of divergent designs, of whatever size and type, is possible by representing the indicated performance of each in the manner described.

The friction mean pressure is discussed briefly. The contention is that, while its variation with speed is large, its value at a given speed is practically independent of load.

The procedure of analysis is applied to a group of engines of varied type and size. A wide divergence among these performances is found, and some reasons for the variations are discussed.

In conclusion, a power-characteristic diagram is added, supplementing the preceding analysis which refers to the individual cycle.

THE existing wide range of Diesel-engine sizes, extending perhaps from 5 to 2000 hp. per cylinder, embraces so great a variety of dimensions, speeds, combustion systems and design details, that comparison between their various performances is likely to be arbitrary. All of these have in common the use of the distinctive principle introduced by Dr. Rudolf Diesel—the self-ignition of fuel in contact with compressed air—but there similarity stops. This dissimilarity hinders any attempt to place various performances on a comparable basis. The situation is not helped by the fact that test results as published are frequently so incompletely stated that a fair estimate of the quality of the design is hardly possible. Occasionally, an engine performance can be recognized as certainly of high merit. In other cases an unusual result may be obtained under special circumstances, yet appear as an unsafe basis upon which to form an opinion.

Granting that limitations must attend any effort to place performances on a universal common basis, there yet seems to be room for a more general statement of engine characteristics than is usually made. The procedure here described has proved useful as a routine analysis of test results. Its application is simple and, given the essential data, it can easily be applied to any size or type. The result is a compact statement of the relative success with which designers have met the problems peculiar to each class of powerplant.

Representation of Ideal-Cycle Efficiencies

It will be useful first to describe a modified presentation of ideal-cycle efficiencies. Published calculations of such cycles show that their efficiencies are a function of the air-fuel ratio, or mixture ratio, as well as of compression ratio. Mixture ratio is usually expressed in terms of the variable

$$\lambda = \frac{\text{Weight of Air Available}}{\text{Weight Required for Combustion}}$$

At light loads λ becomes large, and theoretically it may vary between one and infinity. In practice this wide potential variation makes it awkward to use, especially in conjunction with graphical methods. For λ we may substitute its reciprocal, $X = 1/\lambda$; then, X denotes the air used in combustion as a fraction of the total air present. Its normal range of variation is 0 to 1. In any given instance its value is proportional to the fuel injected (or heat added) per cycle. Curves of ideal efficiency, plotted against X, become nearly

[This paper was presented at the Annual Meeting of the Society, Detroit, Jan. 16, 1935.]

linear instead of asymptotic and are more satisfactory from the standpoint of interpolation.

Now an ideal cycle is characterized not only by its efficiency but by its indicated mean pressure. The latter is a measure of useful work done per cycle per unit volume swept by the piston. The dimensional relation is simply

$$W/V = FL/L^3 = F/L^2 = p_i$$

in which W denotes work; V, volume; F, force; L, length; and p_i, indicated mean pressure in pounds per square inch. Having a certain thermal efficiency and mean pressure corresponding to a given cycle, we may then define a fictitious pressure according to the relation

$$p_g = \frac{p_i}{\eta_t}$$

in which p_g denotes "fuel mean pressure" in pounds per square inch; and η_t, the thermal efficiency of the cycle.

This pressure, like p_i has the dimensions work/volume; that is, p_g is a measure of the *usable heat supplied per unit volume*. It may, therefore, also be definied in terms of X, as follows:

$$p_g = \frac{W}{W_o} \cdot \frac{X H_u \cdot 778 \cdot 12}{V} \qquad (1)$$

in which

W = weight of air present
W_o = weight of air theoretically required to burn 1 lb. of fuel
H_u = lower heating value of the fuel, B.t.u. per lb.
V = swept volume, cu. in.

In a given ideal cycle, each of the latter is a constant; hence, p_g = Constant · X. Therefore, η_t may be plotted against p_g as well as against X or λ.

Fig. 1 shows the result of this rearrangement, for a number of cycles, both Diesel and Otto. The data were taken from Goodenough and Baker[1]. Examination of this diagram will show that it is a combined statement of several essential properties of the cycles.

The abscissa corresponds to the specific supply of heat; the ordinate expresses the efficiency with which that supply is converted to mechanical work. Hyperbolic curves of constant indicated mean pressure are determined by the equation $p_i = \eta_t \cdot p_g$ and may be added to the diagram. The maximum indicated mean pressure for each case, and the efficiency with which it can be developed, is apparent by inspection. While the original cycle calculations were based on specified fuels, the resulting diagram applies with slight error to other liquid fuels as well. Diesel and Otto cycles are therefore compared on the basis of their relative capacities for converting a given supply of heat into useful work. The comparison is not obscured by the fact that fuels ordinarily used in carrying out the respective cycles differ in heating value.

Application to the Actual Engine

Correction for Air Density.—It is evident that the behavior of the actual engine can be expressed in exactly the same terms as has been done for the ideal cycles. In this case the actual specific supply of heat, p_g, is the abscissa; and indicated thermal efficiency, the ordinate. The required data include p_i; g, the weight of fuel injected per cycle; and H_u, for the fuel employed. Only the lower heating value of the fuel is of interest, since we are concerned with the *usable* heat supplied per unit displacement volume. The latter can be calculated directly, in pounds per square inch, according to the equation:

$$p_g = \frac{g \cdot H_u \cdot 778 \cdot 12}{V} \qquad (2)$$

in which V is piston displacement in cubic inches. Thus any test results can be easily transposed to this basis, with several advantages. The points tend to lie along straight or slightly curved lines, facilitating plotting and interpolation, while discrepancies stand out. Supposing the characteristic curve of an ideal cycle to be plotted on the same sheet, the "cylinder efficiency" of the engine may be found by direct comparison. This efficiency is, of course, the ratio of ordinates for the actual and ideal cycles, respectively, at a given abscissa. It represents the relative effectiveness of the two cycles in converting a given heat input, per unit volume, to useful work. The actual cylinder is penalized, in effect, on volumetric efficiency as well as on losses in the combustion process.

But the representation of a test may be misleading if no account is taken of atmospheric conditions, and a suitable adjustment must be made. Referring again to ideal cycles, it is possible to show that all variations due to suction air conditions are explainable in terms of density, rather than in terms of pressure and temperature separately:

(1) Thermal efficiency is determined by X, irrespective of density.

(2) Mean pressure p_i, at a given X, is directly proportional to suction air density.

These statements hold strictly for pressure changes, and with good approximation for temperature changes also.

To allow for the effect of air density we note that

$W = V \cdot \eta_v \cdot \rho$, in which
ρ = air density, and
η_v = volumetric efficiency. Substituting in Equation (1) and simplifying:

$$p_g = \frac{X \cdot \eta_v \cdot \rho \cdot H_u \cdot 778 \cdot 12}{W_o} \quad \text{or,} \qquad (3)$$

$$\frac{p_g}{\rho} = \text{Constant} \cdot X \cdot \eta_v$$

Now η_v is not a constant; but, at a given speed, it varies with load. Certain tests have tended to show that, in fact, η_v is a function of X. Then also $p_g/\rho = f(X)$. Hence, any

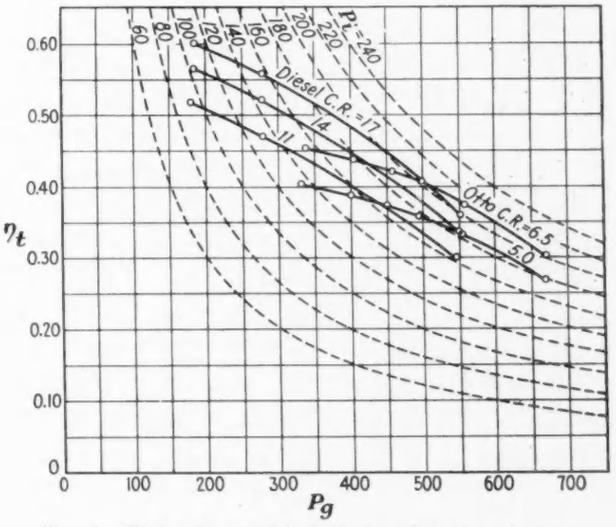


Fig. 1—Efficiencies of Ideal Cycles, Diesel and Otto; from Goodenough and Baker

[1] See Bulletin No. 160, Engineering Experiment Station, University of Illinois, 1927; "A Thermodynamic Analysis of Internal-Combustion-Engine Cycles," by Goodenough and Baker.

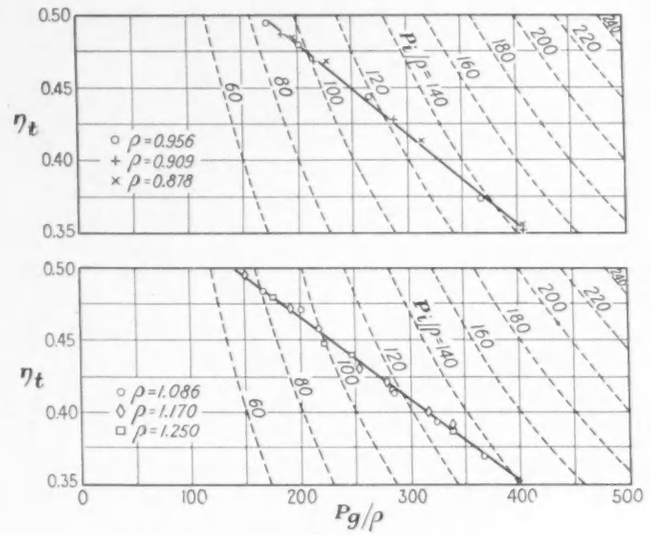


Fig. 2 (*Upper*)—Variable Suction Temperature
Four-Cycle cylinder, 9-in. bore and 12 in. stroke. Speed, 900 r.p.m. Temperature variation, 90 to 140 deg. fahr.

Fig. 3 (*Lower*)—Variable Supercharge Pressure
Four-Cycle cylinder, 9 in. bore and 12 in. stroke. Speed, 900 r.p.m. Temperature variation, 90 to 140 deg. fahr. Pressure variation, 4 to 12 in. of mercury.

property of a cycle—ideal or actual—which can be related to X can be related as well to p_g/ρ.

This proposition lends itself to confirmation by a check against engine tests. Thus we should expect to find that η_t is a function of p_g/ρ, irrespective of air density. Examples of such tests are shown by Figs. 2 and 3. Air density is expressed for convenience in terms of normal atmospheric density (0.075 lb. per cu. ft. at 14.7 lb. per sq. in. and 70 deg. fahr.).

Fig. 2 represents a series of runs of a four-cycle engine in which suction pressure was atmospheric throughout, while suction temperature was varied by artificial heating, from 90 to 140 deg. fahr. The variation of density is from 0.956 to 0.878.

Fig. 3 represents runs of the same engine, assembled with somewhat different elements, and supercharged. The supply pressure varied from 4 to 12 in. of mercury, and the temperature from 92 to 134 deg. fahr. The variation of density is 1.086 to 1.250. In this series, compression ratio was constant; likewise, the ratio of the maximum cycle pressure to absolute suction pressure was maintained constant. These conditions place the ideal cycles on a basis of equality. In each test, the motoring torque of the hot engine at equal suction pressure was accepted as equivalent to friction torque, in arriving at indicated mean pressure.

An inspection of Figs. 2 and 3 will show that the scattering of points has little relation to suction air density, and the adjustment may be considered accurate within ordinary limits of experimental error. For the present purpose, this means that we are justified in using this method for reducing engine performances to standard atmospheric conditions. Incidentally, the results illustrate the linear tendency of the relationship. It will be noticed that the hyperbolic curves now represent constant p_i/ρ.

The Characteristic Curve for a Cylinder

The foregoing reasoning has led to the practice of plotting η_t against p_g/ρ as a useful procedure in analyzing test results. The effect of any modification which may influence efficiency is faithfully represented, whether it be in the air induction system, the pressure cycle, or the combustion process. But, aside from its convenience for this purpose, the diagram is useful as a characteristic by means of which engines of the most diverse kinds can be reasonably compared. The argument for such a comparison runs as follows:

The problem before the designer is, broadly, to devise apparatus for converting the combustion heat of fuel into mechanical work. Two quite general conditions are imposed:

(1) Air as found in the surrounding atmosphere must be inducted and utilized for the support of combustion, and

(2) The fuel must be burned in the working cylinder itself.

Within this scope, we may recognize three factors over which the designer, nominally at least, has control. An acceptable performance characteristic then should measure the success with which these controllable factors have been handled, independently of the other factors which the designer cannot control. The "controllable" factors are:

(1) Volumetric efficiency.

(2) Choice of cycle (Otto or Diesel; compression ratio, and the like).

(3) Details of the combustion process, comprising, in a Diesel, injection system; combustion chamber; turbulence; and control of radiation losses.

These factors set limits; respectively (*a*) to the weight of fuel which may be burned; (*b*) to the extent to which, in the ideal case, the heat of this fuel may be converted to work, and (*c*) to the practical possibilities of approaching the ideal limit set by (*a*) and (*b*).

Factors beyond the control of the designer include the atmospheric conditions under which the engine may operate, and the quality of the fuel. Their influences must be eliminated if a true comparison is to be made. It has already been shown that the variable p_g/ρ appears to be free of objection as to both of these, and it is contended that η_t, plotted on this base is a true measure of the designer's success in dealing with the three "controllable" factors already discussed.

An improvement with respect to any of the controllable factors results in a shift of the characteristic curve upward and to the right. Such a shift corresponds to an increase in both capacity to utilize a large supply of heat and in efficiency of energy conversion.

The characteristic does not necessarily reveal what factor may contribute most to good performance in a particular case; and, indeed, the various factors are interdependent. For example, a combustion chamber fitted with a "hot-spot" feature may gain in respect to factor (*c*), but at the sacrifice of factor (*a*). A similar effect may be produced by an air swirl, or by attempting to limit heat losses unduly. As between large and small cylinders, the small size has the advantage under (*b*), since higher pressures are acceptable, while the larger size should be superior with respect to (*a*). Under (*c*), the large, lower-speed types have better control of the injection and combustion processes. The smaller types may better utilize auxiliary mixing devices such as air chambers, but heat losses are proportionately larger.

Two-cycle and four-cycle cylinders are treated identically in computing the characteristic. The volumetric efficiency of the two-cycle cylinder is generally lower and this will be reflected in the curve. Also, a high piston speed sometimes entails a sacrifice of volumetric or combustion efficiency, and the characteristic may be affected accordingly. But both of these are devices for causing the working cycle to be repeated

Table 1—Details of Engines Represented in Figs. 5 and 6

Case No.	2 or 4 Cycle	Bore, In.	Stroke, In.	Speed, R.P.M.	Piston Speed, Ft. per Min.	Number of Cycles	Normal B.Hp. per Cylinder	p_f	Source	Remarks
1	4	5.5	7.0	1,300	1,517	1	41.0[a]	17.5	D. R. Pye: "The Internal Combustion Engine"	$\rho = 1$ (assumed)
2	4	22.0	25.2	169	710	6	210.0	25.2	A. Stodola: "Dieselmaschinen IV"; V.D.I., Berlin	Supercharged
3	4	9.0	12.0	900	1,800	4-12	66.7	27.6-22.6	Author's data	
4	4	8.0	11.0	1,000	1,835	1	84.2[a]	13.1	H. B. Taylor: "The Automobile Engineer"; November,1927	$\rho=1$ (assumed) max. pr. = 800
5	4	8.0	11.0	1,000	1,835	1	84.1[a]	13.1	H. B. Taylor: "The Automobile Engineer"; November,1927	$\rho=1$ (assumed) constant timing
6	2	10.0	12.0	900	1,800	1	150.0	17.3	Author's data	
7	2	33.9	59.0	94	925	9	1,600.0	12.7	W. Laudahn: V.D.I. Zeitschrift; October 23, 1926	$\rho = 1.02$ (estimated)
8	2	23.6	35.5	214	1,266	10	1,060.0	11.9	W. Laudahn: "Dieselmaschinen V"; V.D.I., Berlin	
9	2	27.6	47.2	90[b]	708	6	740.0	6.4	F. Romberg: "Dieselmaschinen IV"; V.D.I., Berlin	Marine Engine Blower separate
10	4	18.1	24.8	216	892	4	129.0	16.2	F. Romberg: "Dieselmaschinen III"; V.D.I., Berlin	$\rho = 1$ (assumed)

[a] Maximum [b] At rated load

more frequently, and so may result in a net gain. It is not possible to allow for these differences in a characteristic which refers to the individual cyclic process. Proper allowance may easily be made by other means, and this will be referred to later.

The Friction Mean Pressure

To this point we have dealt with indicated power only. In order to interpret actual test results, friction torque must be known, expressed preferably as friction mean pressure, or p_f.

High-speed engines are notoriously difficult to indicate, and indicated mean pressure, as read from a *P-V* card, is especially unreliable because the card area is sensitive to even a very slight angular lag in the pressure readings. Motoring torque is as yet the most dependable measure of friction, at least for speeds of perhaps 600 r.p.m. and higher.

Several published tests of lower-speed engines include careful measurements of indicated mean pressure, p_i being found by difference. A review of the data (as in Cases 2 and 8, Table 1) shows no particular trend of p_f with load, the values scattering at random within narrow limits. This suggests that an average p_f, used as a constant, is more precise than the individual values. Taking brake mean pressure, p_e, as observed, indicated pressure is then recalculated as $p_i' = p_e + p_{f(av.)}$.

Data so recalculated were found to have somewhat better consistency than when in the original form. Fig. 4 shows the results of a test by Dr. A. Stodola of a supercharged four-cycle engine. (Case 2, Table 1.) The "recalculated" data are noticeably more consistent. In this case, p_f varied from 24.2 to 26.8, and averaged 25.2. For Case 8, p_f varied from 6.2 to 6.5, and averaged 6.3. Such results confirm the use of a constant p_f at a given speed, irrespective of load. Of course, it does not necessarily follow that p_f from a motoring test is the "true" value, even though it be the best approximation.

A part of the designer's task is to make p_f small, but it is important in an analysis that its effects be kept separate. The cylinder characteristic is the same wherever the type is repeated, whether in a one-cylinder or in a ten-cylinder engine, and it may be derived from a test of either. On the other hand, p_f varies with the number and arrangement of cylinders and is subject to arbitrary change, since auxiliaries may be added or omitted.

Examples of Cylinder Characteristics

An attempt was made to assemble a group of characteristic curves which would include representatives of the widest possible range. The results are given by Fig. 5, while the details of the various cases are listed in Table 1. A fair selection of tests could be found, principally of medium and large sizes, and those chosen represent practice in divergent fields. For the cases selected, the required data were practically complete; though, in a few, it was necessary to assume or estimate air density where noted in Table 1. The length of the line as plotted corresponds to the actual range of the test. A heavy dot in the curve indicates the normal rating point.

Case 1 is the experimental "air-swirl" engine developed by

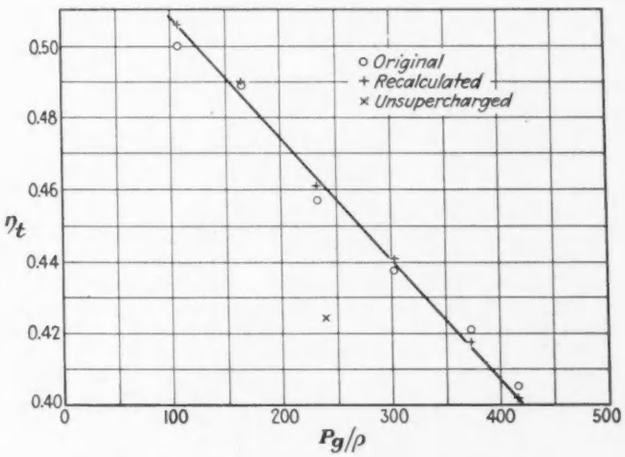


Fig. 4—Test of a Supercharged Four-Cycle Engine
From Dr. A. Stodola's data; showing the effect of recalculation with p_f = constant

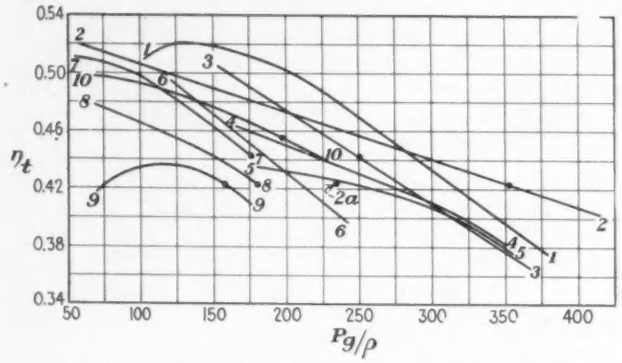


Fig. 5—Cylinder Characteristics for Various Engines

H. R. Ricardo, employing a sleeve valve. The results are remarkably good and are due presumably to the success of the peculiar combustion system.

Case 2 is supercharged by means of an exhaust turbo-blower. The blower increases volumetric efficiency in terms of atmospheric air. As a result, the slope of the characteristic line is less steep than normal and extends to exceptionally high values of p_g/ρ. The single point 2*a* represents the behavior of the same engine without supercharge, and emphasizes the increased return for a given heat supply when a greater surplus of air is present.

Case 3 is an example of a moderately high-speed and light-weight four-cycle type, suitable for railway and other portable service.

Cases 4 and 5 represent some of the pioneer work in high-speed-Diesel development done at the Royal Aircraft Establishment in England.

Case 6 is an example of a two-cycle design of relatively high speed.

Cases 7 and 8 are both large two-cycle double-acting engines in central-station service. The lower efficiency of Case 8, the smaller one, is associated with a higher operating speed.

Case 9 is a marine type, and the peculiar shape of the curve is partly due to the fact that this is a variable-speed test. At light load, the speed is 56 r.p.m. and, at overload, 93 r.p.m.

Case 10 is a relatively low-speed four-cycle mechanical-injection engine, and is probably typical of its class.

Several types which should have a place in a representative group had to be omitted for lack of information. For example, no complete test of an automotive Diesel could be found, interesting though that case might be.

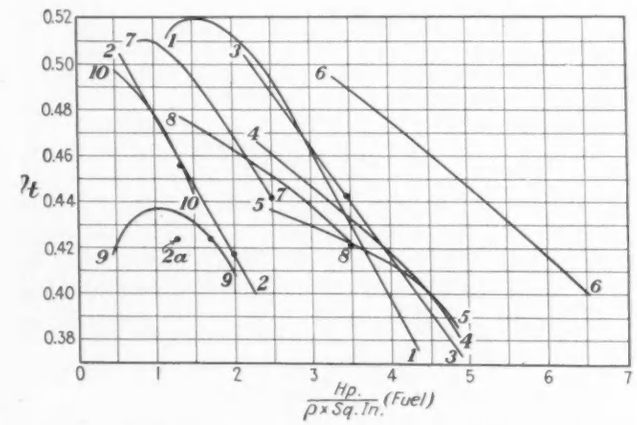


Fig. 6—Indicated-Horsepower Characteristics of Cylinders

Regarding the group as a whole, perhaps the most notable features are: (*a*) the effectiveness of supercharging in improving both efficiency and power capacity, and (*b*) the outstanding performances of the small high-speed designs. At one stage in Diesel development, both small size and high speed appeared as serious handicaps. Whatever obstacles they once presented have been entirely overcome. In fact, some of the advantages possessed by this class are inherent and could scarcely be transferred to a cylinder of the size and speed which was acceptable ten years ago.

Every curve slopes downward to the right. This is a fundamental property which the actual cycles share with the ideal. It is one which cannot be ignored if thermal efficiency is to be discussed with precision.

Frequency of Power Cycle

It has been pointed out that both high running-speed and two-cycle operation are devices for increasing the frequency of the power cycle. These effects can be allowed for in an obvious manner. We have so far dealt with work per unit of swept volume. We may now substitute power per unit of piston area. This is conveniently done by expressing heat input as "fuel horsepower" per square inch of piston area:

$$\text{Fuel Hp. / Sq. In.} = \frac{S \cdot N \cdot p_g}{33{,}000 \cdot 12} \quad \text{(Two Cycle) or} \quad (4)$$

$$= \frac{S \cdot N \cdot p_g}{2 \cdot 33{,}000 \cdot 12} \quad \text{(Four Cycle)} \quad (5)$$

We have seen that p_g/ρ is preferable to p_g, in order to correct for atmospheric variations, and the same arguments apply in this case as well. Hence, the abscissa becomes Fuel Hp. /Sq. In. $\times$ ρ. Against this, as before, we then plot η_t. The diagram then represents (*a*) the usable combustion heat supplied per square inch of piston area per unit time (this could be reduced to B.t.u. per min. per sq. in., for example); and (*b*) the efficiency with which this heat is converted to power, with the necessary correction for atmospheric conditions. Hyperbolic curves of constant I. Hp./Sq. In. $\times$ ρ can be added if desired. The abscissa is a fair measure of the "thermal load" applied to the engine, but the capacity to carry such loads is largely influenced by the details of design and by the efficiency of the working cycle.

While this diagram does not have a direct relation to the theoretical ideal cycle as does that of Fig. 5, it is of practical use as a further means of analysis. Neither diagram is non-dimensional as regards the abscissa, but either is seemingly a proper comparison. For example, to refer output to a unit of cylinder volume (hp. per cu. in.) gives a dimensional advantage to the small engine. This objection does not hold if we refer to a unit of piston area.

Fig. 6 shows the results for the same engines included in Fig. 5 and Table 1, and is self-explanatory.

Conclusion

Two uses are suggested for the method of analysis which has been described:

(1) As a research tool, affording exact knowledge of the influence of any factor upon the combustion cycle.

(2) As a means of comparing competitive designs in the same field. For example, a study of the diverse combustion systems among automotive Diesels should prove instructive.

(Concluded on page 236)

C.F.R. Committee Report on 1934 Detonation Road Tests Discussed

THE object of the 1934 C.F.R. detonation road tests was (*a*) to check the validity of correlation between road knock-ratings and laboratory knock-ratings, and (*b*) to indicate promising paths of research directed toward better mutual adaptation of fuels and engines.

The report describing these tests, "C.F.R. committee Report on 1934 Detonation Road Tests," was published in the May, 1935, S.A.E. JOURNAL, beginning on page 165. It reports on materials and equipment, road-test procedure, supplementary test methods, special reference fuels and results, engine severity-factor and factors affecting fuel-engine relationships. Detonation research is reported upon, and C.F.R. road-test-method specifications are stated in the Appendix.

Available Data Analyzed Further

—Donald B. Brooks
National Bureau of Standards

Car Variability

SINCE in the Uniontown tests only one to three cars of each make were used, it is quite possible that the results are not representative of the average for the make. To determine how cars of one make differ from their average, tests should be run on at least twenty-five units.

Through the generous cooperation of Washington dealers, the National Bureau of Standards has been able to run road tests on a series of eight fuels, on each of 29 cars of the make represented at Uniontown by Cars 4, 5, and 6. Most of these tests were run during October and November, 1934, part being made on Mount Vernon Boulevard, using the Bureau's Traction Dynamometer, and part on a hill (8 per cent grade, straight, ½ mile long) near Hyattstown, Md. The C.F.R. Road-Test procedure was used throughout.

On each of the first 27 cars, the series of eight fuels was rated once only. In these tests, the test and reference fuel were identified as in the Uniontown tests. On each of the last two cars, the series of eight test-fuels was rated twice daily for five consecutive days. In these last tests, not only were the test and reference fuels blind, but the reference fuels were not made up in even intervals. Thus, each fuel carried a tag marked as in Col. 1 of Table *A*, which shows the results obtained for one series of ratings of the eight test-fuels in one car. As all fuels were dyed red, this was all the observer knew of the fuel. The observer reported knock values at each 5 m.p.h. over the knocking range. From these data, the maximum knock values given in Cols. 2 to 4 were obtained by plotting. Whenever the knock for any fuel approached the maximum permissible, the rating of this fuel was repeated with spark reset for low knock-intensity. In Table *A* this was done on samples 2-H-5 and 2-H-12.

When the maximum knock values had been obtained, the samples were identified (Col. 5) and the ratings were found (Col. 6) from the knock values. For comparison, Col. 7 gives the average ratings obtained on this car. It should be noted that the procedure used in these tests keeps both the observer and the computer in the dark as to the identity of the test and reference fuels until the final knock values are obtained. While this procedure involves somewhat more care and planning, all those who were concerned in these tests are agreed that it is much more satisfactory than open testing.

All of the results obtained in these last two cars are given in Table *B*. As in the earlier tests, Fuel N.B.S.-4 was too high to rate satisfactorily; this fuel was consequently left out

Table *A*—(Brooks Discussion)

Sample	Maximum Knock			Identification	Rating, Per Cent C-8	Average Rating for 10 Trials on This Car Per Cent C-8
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7
2-H-1	2.2	....	....	N.B.S.—4B	>116	>116
2-H-2	4.5	....	....	116 per cent[a] C-8	.....	.....
2-H-3	7.6	....	....	N.B.S.—3	102	99.5
2-H-4	8.2	....	....	100 per cent C-8	.....	.....
2-H-5	11.8	1.3[b]	....	91.7 per cent C-8	.....	.....
2-H-6	....	2.8	....	N.B.S.—6	83.5	85.0
2-H-7	....	2.8	....	83.3 per cent C-8	.....	.....
2-H-8	....	5.2	....	N.B.S.—5	79.5	80.3
2-H-9	....	6.4	....	N.B.S.—2	77.5	80.2
2-H-10	....	8.1	....	75 per cent C-8	.....	.....
2-H-11	....	6.2	....	N.B.S.—1	78	73.8
2-H-12	....	11.5	1.3[b]	N.B.S.—8	65.5	66.8
2-H-13	....	....	1.7	62.5 per cent C-8	.....	.....
2-H-14	....	....	4.0	55.6 per cent C-8	.....	.....
2-H-15	....	....	7.9	N.B.S.—7	50	51.5
2-H-16	....	....	7.9	50 per cent C-8	.....	.....

[a] Lead in C-8.
[b] Spark reset for low knock intensity.

Table *B*—(Brooks Discussion). Road Ratings; Per Cent of C-8 in A-3

Run No.	N.B.S.-1	N.B.S.-2	N.B.S.-3	N.B.S.-4B	N.B.S.-5	N.B.S.-6	N.B.S.-7	N.B.S.-8	Sum of Ratings (Except N.B.S.-4B)
				Car 28					
1	73	77	101	107.5	75.5	81.5	51	64.5	523.5
2	71.5	77.5	100	>108	76.5	88.5	57.5	59	530.5
3	66	72	106	>110	74	87	53	68	526
4	72.5	78	110	>110	73.5	77.5	47	69.5	528
5	71	77.5	100.5	>108	70.5	80.5	46	62	508
6	78	82.5	102.5	>108	78.5	84.5	49.5	64.5	540
7	77.5	75.5	113	>116	78	82	46	65.5	537.5
8	71	73.5	107.5	>116	76	75.5	55.5	67	526
9	71.5	73	103	>116	70.5	88	51.5	67	524.5
10	72	80	100	>116	78	80	49	65	524
Average	72.4	76.6	104.4	>116	75.1	82.5	50.6	65.2	526.8
Probable Error	2.3	2.2	3.1	...	2.0	3.0	2.6	2.0	5.9
				Car 29					
1	72.5	76.5	110.5	>116	76.5	87	51	69.5	543.5
2	72.5	83	99	>116	79	87	52.5	69	542
3	66.5	80	102.5	>116	81.5	87.5	51	65	534
4	71.5	81.5	105	>116	81	88.5	51.5	66	545
5	73.5	81	95	111	78	81	51	65	524.5
6	75	85	97.5	>116	82.5	91	51	68.5	550.5
7	80.5	79.5	93	>116	80	83.5	54.5	65.5	536.5
8	78	77.5	102	>116	79.5	83.5	50	65.5	536
9	71.5	75	99.5	>116	81.5	78.5	50.5	67.5	524
10	76	82.5	91	111	83.5	82.5	52	66	533.5
Average	73.8	80.2	99.5	>116	80.3	85.0	51.5	66.8	537.0
Probable Error	2.6	2.1	3.9	...	1.4	2.6	0.9	1.2	5.8

of further consideration. Since ten ratings were obtained on each car, the variations of these ten sets of ratings, as indicated by the sums of ratings (last column of Table *B*), reflects all sources of error except change of car. From these data, particularly from the probable errors, it is possible to predict how the earlier ratings should vary if all cars were essentially alike. This prediction is plotted in Fig. *A*.

The data actually obtained are summarized in Table *C* and are plotted in Fig. *B*. It is obvious that Fig. *B* bears only a superficial resemblance to Fig. *A*. The data scatter over a decidedly wider range than in the prediction. The question naturally arises, is this increased scattering caused by a large proportion of the cars departing a relatively small amount from the mean, or by a small proportion departing more widely? This question cannot be answered with exactness, as even the number of units used in these tests is not sufficient to eliminate the elements of chance from the results. However, by a number of trial-and-error approximations, the revised "prediction" shown in Fig. *C* was obtained, which duplicates the observed distribution very closely. The basis for Fig. *C* is that, superposed on the normal distribution shown in Fig. *A*, three of the cars rated all fuels 5 per cent C-8 below average, and three cars rated them 5 per cent C-8 above average.

This assumption, which is not unreasonable and which reconciles the facts with the Theory of Errors, means that ¼

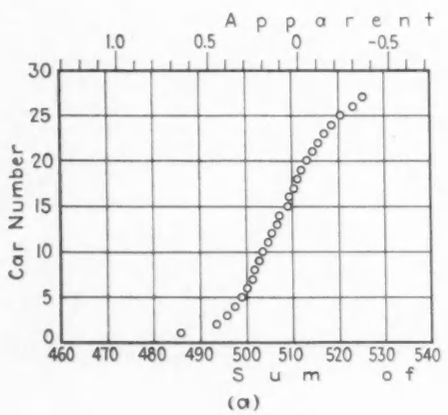


Fig. *A*—(Brooks Discussion) Normal Distribution of Car Data

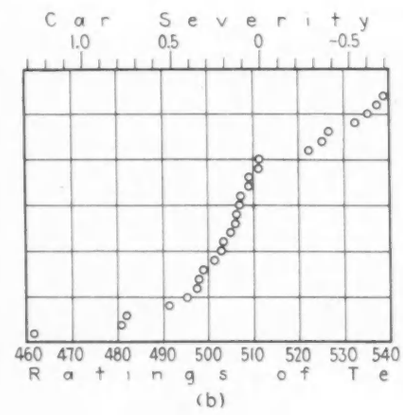


Fig. *B*—(Brooks Discussion) Car Data

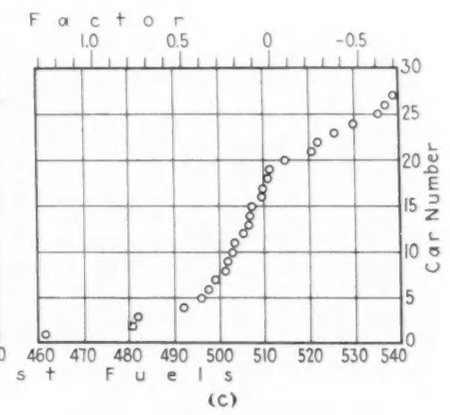


Fig. *C*—(Brooks Discussion) Simulated Car Data

or 1/5 of the cars of this particular make rate fuels 1½ octane units higher or lower than average. On this basis, the probable effect of car variability on the Uniontown results is as follows:

No. of Units Used	Probable Variation from Average for Make; Octane Units
1	0.38
2	0.33
3	0.29
4	0.26

In Figs. *A* to *C*, a severity-factor scale is included to demonstrate the variations in this value which can arise by chance.

Engine Severity Factors

The concept of engine severity factors, deduced by the writer from a study of National Bureau of Standards road tests made in the Spring and early Summer of 1932, and applied[a] to the 1932 Uniontown test results, is now coming into general use. In consequence the question arises: Does this concept accurately represent the facts, or is it only a convenient approximation?

The fact that the severity factors obtained by rating various fuels in one engine are different is not significant, as several sources of error are known which can cause relatively large errors in factors computed from individual ratings. To answer the question it is necessary to know whether the observed variations in the severity factor can be accounted for quantitatively by the known errors.

In determining engine severity factors, it is necessary to have accurate Motor and Research-Method ratings of the fuels used. The Detonation Subcommittee's Motor-Method values for the Uniontown fuels are probably the most accurate ratings ever obtained on a series of fuels. Unfortunately, their Research-Method ratings are far from accurate. These values were obtained by only seven of the 19 cooperating laboratories.

[a] (Brooks Discussion) See S.A.E. JOURNAL, May, 1933, p. 187.

Table C—(Brooks Discussion) Car Data Summarized

Car No.	Sum of Ratings of 7 Fuels	1934 Date	Sea-Level Barometer, mm. Hg.	Temperature, Deg. Fahr.	Humidity, mm. Hg.
1[a]	565.7	5–31	759	82	12
2[a]	568.7	6–15	757	86	10
3	532.5	6–19	753	80	16
4	495.3	7–2	761	91	15
5	535.3	7–5	763	89	20
6	506.4	7–5	762	94	20
7	497.6	9–24	770	78	19
8	502.9	10–3	768	68	8
9	504.9	10–7	761	68	6
10	509.0	10–9	768	74	11
11	511.3	10–13	762	48	4
12	501.5	10–14	766	52	4
13	506.2	10–17	770	64	13
14	509.3	10–18	765	70	12
15	491.4	10–19	766	57	6
16	538.8	10–20	766	61	5
17	498.9	10–21	760	64	11
18	522.3	10–22	757	71	8
19	503.4	10–23	762	64	8
20	511.3	10–24	765	61	9
21	525.3	10–25	762	62	8
22	498.1	10–26	756	60	5
23	480.9	10–27	753	51	6
24	507.2	10–28	762	46	3
25	507.0	10–29	761	53	4
26	461.4	10–30	768	52	4
27	482.4	10–31	762	57	7
28–1	523.5	11–5	761	62	7
28–2	530.5	11–5	758	64	7
28–3	526.0	11–6	757	56	7
28–4	528.0	11–6	757	56	5
28–5	508.0	11–7	752	60	5
28–6	540.0	11–7	750	66	6
28–7	537.5	11–8	760	49	6
28–8	526.0	11–8	759	53	7
28–9	524.5	11–9	772	44	3
28–10	524.0	11–9	770	48	3
29–1	543.5	11–12	762	40	4
29–2	542.0	11–12	761	42	3
29–3	534.0	11–13	757	42	3
29–4	545.0	11–13	753	50	3
29–5	524.5	11–14	767	40	4
29–6	550.5	11–14	768	39	3
29–7	536.5	11–15	773	38	2
29–8	536.0	11–15	771	47	2
29–9	524.0	11–16	772	51	4
29–10	533.5	11–16	770	57	2

[a] These tests were omitted from the discussion as they were run by an inexperienced observer.

Table D—(Brooks Discussion). Individual Values

UT No. of Fuel		1		3		4		6		13		14		16		12		5	
Car		Factor	Error	Factor	Error	Factor	Error	Factor	Error	Factor	Error	Factor	Error	Factor	Error	Factor	Error	Factor	Error
1		0.57	0.22	0.98	0.27	2.14	0.76	2.93	0.75	1.09	0.41	2.86	0.66	−0.30	0.62	0.63	0.06	0.61	0.13
2		0.34	0.23	0.43	0.28	1.07	0.45	1.95	0.55	1.52	0.42	1.67	0.37	0.59	0.58	0.52	0.06	0.69	0.13
3		0.34	0.23	0.98	0.27	1.79	0.63	1.71	0.52	1.09	0.41	1.91	0.42	0.59	0.58	0.73	0.05	0.76	0.13
4		0.45	0.22	0.22	0.30	−0.36	0.78	2.44	0.64	0.00	0.45	1.67	0.37	−2.06	0.81	0.45	0.06	0.61	0.13
5		0.11	0.25	0.98	0.27	0.71	0.46	1.22	0.48	1.74	0.44	2.38	0.54	0.30	0.59	0.55	0.06	0.23	0.14
6		0.34	0.23	0.76	0.27	1.79	0.63	2.44	0.64	2.39	0.50	.....	.....	2.35	0.65	1.18	0.05	0.76	0.13
7		1.59	0.23	.....	.....	−1.79	1.43	3.17	0.81	1.96	0.45	.....	.....	0.88	0.58	1.41	0.06	0.84	0.13
7′		1.48	0.22	0.87	0.27	0.71	0.46	2.68	0.69	1.96	0.45	.....	.....	3.82	0.82	1.20	0.06	0.99	0.13
8		1.48	0.22	.....	.....	1.07	0.45	1.71	0.52	1.74	0.44	.....	.....	1.18	0.58	1.18	0.05	1.07	0.13
9		0.57	0.22	.....	.....	0.00	0.64	2.44	0.64	1.74	0.44	1.43	0.33	1.18	0.58	0.86	0.05	0.92	0.13
10		0.91	0.21	1.31	0.28	1.07	0.45	2.44	0.64	2.18	0.47	.....	.....	3.24	0.74	0.65	0.06	0.69	0.13
11		0.91	0.21	.....	.....	2.50	0.91	1.71	0.52	1.09	0.41	1.43	0.33	1.18	0.58	.....	.....	0.61	0.13
11′		0.57	0.22	0.11	0.31	2.50	0.91	0.98	0.47	.....	.....	.....	.....	1.18	0.58	1.02	0.05	0.08	0.14
12		1.36	0.22	.....	.....	0.36	0.53	1.95	0.55	3.04	0.58	.....	.....	2.65	0.68	.....	.....	0.99	0.13
13		.....	.....	.....	.....	2.14	0.76	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
13′		0.91	0.21	.....	.....	3.57	1.41	2.93	0.75	2.18	0.47	.....	.....	1.47	0.59	.....	.....	0.92	0.13
13″		.....	.....	0.87	0.27	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.73	0.05	.....	.....
14		.....	.....	.....	.....	0.71	0.46	.....	.....	.....	.....	3.10	0.73	.....	.....	.....	.....	.....	.....
15		0.57	0.22	0.65	0.28	3.22	1.24	1.95	0.55	1.74	0.44	.....	.....	0.88	0.58	0.68	0.06	0.84	0.13
16		0.91	0.21	.....	.....	0.71	0.46	1.71	0.52	0.22	0.43	4.29	1.08	.....	.....	.....	.....	0.61	0.13
17		0.45	0.22	1.09	0.27	.....	.....	1.95	0.55	2.18	0.47	.....	.....	1.18	0.58	.....	.....	0.92	0.13
18		0.91	0.21	2.28	0.35	1.07	0.45	.....	.....	.....	.....	.....	.....	2.65	0.68	.....	.....	1.68	0.15
18′		.....	.....	1.85	0.30	.....	.....	3.90	1.00	3.70	0.68	.....	.....	3.24	0.74	1.28	0.06	.....	.....
19		1.48	0.22	1.85	0.30	3.93	1.58	2.20	0.60	2.61	0.52	.....	.....	3.24	0.74	1.39	0.06	1.83	0.15
No. of Values	Within Prob. Error of Mean	9		7		8		3		4		0		11		5		8	
	Beyond Prob. Error from Mean	11		8		13		17		15		9		9		11		12	

Three of the seven used C-7 as a reference fuel; the calibrations they used in converting to octane number differed by as much as three octane units. Of the remaining four laboratories, three did not report reference fuels, and may also have used different calibration curves, as no standard curve exists. The ratings, thus variously converted to octane number by the various laboratories, were then converted to per cent of C-8 in A-3 by use of the standard Motor-Method calibration, which differs from the Research-Method calibration by 2 octane units in the ranges in question. In consequence, in the ensuing discussion, only Research ratings determined directly in per cent of C-8 in A-3 have been used in deriving average Research-Method values for the Uniontown fuels.

The engine severity factor, F, is

$$F = \frac{R - C}{R - M} \qquad (1)$$

where

R = Research-Method Rating
M = Motor-Method Rating
C = Car Rating

In Equation (1), R, M, and C are all subject to error. Calling these probable errors "r" with the appropriate subscript, and letting $R - C = S_C$ and $R - M = S_L$, then the probable error of F is given by

$$r_F^2 = \frac{(S_L - S_C)^2 r_R^2 + S_L^2 r_C^2 + S_C^2 r_M^2}{S_L^4} \qquad (2)$$

The values of r_R and r_M for each fuel were found from the deviations of the various laboratory ratings of that fuel. The value of r_C has been estimated for each Uniontown fuel from the data obtained in N.B.S. road tests and given in Table B, herein.

Table D gives the severity factor and its probable error computed by means of Equation (2) for each Uniontown road rating. To understand Table D it is necessary to have a clear conception of the term "probable error." The difference between an observation and its true value is as likely to exceed the probable error as it is to be less. Hence, in any extended series of measurements having no systematic error, half of the observations must lie within their true probable error of the mean.

The last two columns and the last two rows of Table D list for each car and for each fuel the number of cases in which the difference between the observed factor and the mean factor for the car is greater than, and is less than, the

of Car Severity Factors and Their Probable Error

10		8		2		9		11		7		15		Mean		No. of Values	
Factor	Error	Factor	Error	Factor	Error	Factor	Error	Factor	Error	Factor	Error	Factor	Error	Factor	Error	Within Prob. Error of Mean	Beyond Prob. Error from Mean
0.92	0.12	0.44	0.15	0.50	0.22	1.35	0.26	0.68	0.16	1.10	0.16	0.00	0.89	0.85	0.05	5	11
0.71	0.12	0.88	0.13	0.10	0.25	0.68	0.26	0.34	0.17	–0.25	0.17	0.00	0.89	0.57	0.05	8	8
0.50	0.12	0.71	0.14	0.40	0.22	0.95	0.26	0.88	0.16	–0.42	0.18	–0.37	0.97	0.69	0.05	6	10
0.00	0.14	1.24	0.14	–0.70	0.34	0.00	0.27	.....	.....	.....	.....	–2.96	1.87	0.29	0.06	4	10
0.00	0.14	0.27	0.16	–0.30	0.29	0.27	0.26	0.54	0.16	–1.10	0.21	–0.37	0.97	0.35	0.05	7	9
0.50	0.12	0.71	0.14	–0.40	0.30	1.22	0.26	0.54	0.16	–1.27	0.21	–1.11	1.19	0.70	0.05	4	11
1.56	0.12	1.33	0.14	1.50	0.22	1.49	0.26	.....	.....	0.68	0.16	.....	.....	1.31	0.05	4	8
0.99	0.12	1.15	0.14	0.90	0.20	1.62	0.26	1.29	0.16	1.02	0.16	–0.74	1.08	1.23	0.05	3	12
1.21	0.12	1.50	0.15	.....	.....	0.81	0.26	.....	.....	0.76	0.16	.....	.....	1.19	0.05	6	5
0.99	0.12	0.88	0.13	.....	.....	1.35	0.26	.....	.....	.....	.....	.....	.....	1.00	0.05	4	7
0.71	0.12	0.97	0.13	0.30	0.23	1.35	0.26	0.82	0.16	0.42	0.16	–0.74	1.08	0.88	0.05	4	11
0.35	0.13	0.71	0.14	1.20	0.20	0.68	0.26	.....	.....	0.42	0.16	1.85	0.87	0.86	0.07	4	9
0.64	0.12	0.27	0.16	0.80	0.20	0.68	0.26	0.20	0.17	1.36	0.16	1.48	0.81	0.72	0.05	7	7
1.13	0.12	1.24	0.14	1.00	0.20	1.49	0.26	1.02	0.16	0.59	0.16	0.37	0.83	1.20	0.06	5	8
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.14	0.76	1	0
0.78	0.12	0.97	0.13	1.10	0.20	1.08	0.26	.....	.....	0.68	0.16	1.48	0.81	1.17	0.07	4	8
.....	.....	.....	.....	0.80	0.20	.....	.....	0.54	0.16	.....	.....	0.00	0.89	0.70	0.07	5	0
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.14	0.42	0	2
0.71	0.12	0.71	0.14	0.30	0.23	0.81	0.26	0.82	0.16	0.42	0.16	0.00	0.89	0.77	0.05	9	6
.....	.....	0.88	0.13	.....	.....	.....	.....	.....	.....	0.68	0.16	.....	.....	1.02	0.08	2	6
0.28	0.13	0.35	0.15	0.00	0.26	0.95	0.26	0.68	0.16	.....	.....	0.00	0.89	0.71	0.07	4	8
0.99	0.12	1.24	0.14	0.00	0.26	1.75	0.27	.....	.....	.....	.....	.....	.....	1.30	0.07	2	7
.....	.....	1.42	0.14	1.00	0.20	2.70	0.29	1.02	0.16	0.42	0.16	.....	.....	1.53	0.06	1	9
1.85	0.14	1.86	0.17	1.70	0.23	1.62	0.26	1.36	0.16	1.61	0.17	1.11	0.79	1.71	0.05	9	6
7		12		6		10		7		1		10				108	
12		9		13		10		7		16		6					178

computed probable error. Car 18-18′ and Fuels 6, 7, 13 and 14, are seen to have a low ratio of "within" to "beyond." It appears that in these cases the severity-factor idea does not fit so well. However, Fuel 7 is a benzol blend; Fuel 14 has the lowest rating, and knocked severely in most cars.

All the foregoing is based on the assumption that the probable error of the Uniontown ratings—each being assumed to be the average of two road tests—is 0.56 octane unit, this being deduced from the N.B.S. ratings mentioned earlier. The N.B.S. data were obtained by an observer who had been working on the one make of car six or seven days a week for over a month, while in the Uniontown tests the observers changed cars almost daily.

If this be considered sufficient cause to place the probable error of the Uniontown ratings as high as 0.8 octane unit, then there would be, in a correspondingly revised Table *D*, exactly as many values within their probable error of the mean as beyond it. This would mean, of course, that the severity-level concept fits the data within experimental error. Even on this assumption, however, Fuels 7 and 14 are still out of line.

Table *E* lists for each Uniontown rating, the fuel sensitivity ("depreciation" in the car of the fuel from its Research-Method rating) computed from the mean engine severity factor for the car in question (from Table *D*) and the difference between the observed sensitivity and the computed value. From these differences, the probable error is inferred for each car (last column) and for each fuel (next to last row). The last row gives average difference between observed and computed values for each fuel. The average probable error for all ratings is 3.4, as shown at the lower right corner of Table *E*. This average can also be computed, using the road-test-error values derived from N.B.S. tests, as explained earlier. The value so found is 3.29. That is, the value 3.29 was obtained from repeat tests on one fuel in one car, and 3.4 was obtained from the 16 Uniontown fuels in 20 Uniontown cars, by assuming that the severity-level concept fits. Thus the severity-level concept predicts the 286 Uniontown ratings practically as well as one would expect to predict the rating of one fuel in one car; or, in other words, it reduces cars to a common basis.

In conclusion, it is evident that engine severity factors can be applied without hesitation in the case of normal fuels. It can be inferred from the Uniontown data, and is demonstrated definitely by other unpublished data, that such is not the case with certain abnormal fuels, notably benzol blends.

Table E—(Brooks Discussion)—Computed

UT No. of Fuel	1		3		4		6		13		14		16		12	
Car	Computed	Observed-Computed	Computed	Observed-Computed	Computed	Observed-Computed	Computed	Observed-Computed	Computed	Observed-Computed	Computed	Observed-Computed	Computed	Observed-Computed	Computed	Observed-Computed
1	7	−2	8	1	2	4	3	9	4	1	4	8	3	−4	32	−8
2	5	−2	5	−1	2	1	2	6	3	4	2	5	2	0	22	−2
3	6	−3	6	3	2	3	3	4	3	2	3	5	2	0	26	2
4	3	1	3	−1	1	−2	1	9	1	−1	1	6	1	−8	11	6
5	3	−2	3	6	1	1	1	4	2	6	1	9	1	0	13	8
6	6	−3	6	1	2	3	3	7	3	8	.....	.....	2	6	27	18
7	12	2	.....	.....	4	−9	5	8	6	3	.....	.....	4	−1	50	4
7′	11	2	11	−3	3	−1	5	6	6	3	.....	.....	4	9	47	−1
8	11	2	.....	.....	3	0	5	2	5	3	.....	.....	4	0	46	−1
9	9	−4	.....	.....	3	−3	4	6	5	3	4	2	3	1	38	−5
10	8	0	8	4	2	1	4	6	4	6	.....	.....	3	8	34	−9
11	8	0	.....	.....	2	5	4	3	4	1	4	2	3	1	.....	.....
11′	6	−1	7	−6	2	5	3	1	.....	.....	.....	.....	2	2	27	12
12	11	1	.....	.....	3	−2	4	4	6	8	.....	.....	4	5	.....	.....
13	.....	.....	.....	.....	6	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
13′	10	−2	.....	.....	3	7	5	7	5	5	.....	.....	4	1	.....	.....
13″	.....	.....	6	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	27	1
14	.....	.....	.....	.....	6	−4	.....	.....	.....	.....	9	4	.....	.....	.....	.....
15	7	−2	7	−1	2	7	3	5	4	4	.....	.....	3	0	29	−3
16	9	−1	.....	.....	3	−1	4	3	5	−4	4	14	.....	.....	.....	.....
17	6	−2	6	4	.....	.....	3	5	3	7	.....	.....	2	2	.....	.....
18	11	−3	12	9	4	−1	.....	.....	.....	.....	.....	.....	4	5	.....	.....
18′	.....	.....	14	3	.....	.....	6	10	7	10	.....	.....	5	6	59	−10
19	15	−2	16	1	5	6	7	2	8	4	.....	.....	6	5	66	−13
r_1	1.4		2.7		2.8		4.1		3.5		5.1		3.0		5.6	
Average Residual	−1.0		+1.5		+1.0		+5.4		+3.8		+6.1		+1.9		−0.1	

Appendix

Computation of Probable Error of Severity Factor.—Equation (2) above is a rigorous formula for computation of probable error of the severity factor, but can be simplified without material loss of accuracy.

If a large number of Research and Motor-Method ratings of each fuel are available, so that the principal error is that of the road ratings, Equation (2) becomes

$$r_F = \frac{r_C}{S_L} \tag{3}$$

If only one laboratory rating by each method is used, and if the error of laboratory and road ratings be assumed to be equal, and designated r_T, Equation (2) becomes

$$r_F = \frac{r_T\sqrt{2}}{S_L} \quad \sqrt{1-F+F^2} \tag{4}$$

For rough values, particularly if F lies between −0.5 and +1.5, Equation (4) can be reduced to

$$r_F = \frac{r_T\sqrt{2}}{S_L} \tag{5}$$

Severity-Factor Calculation Exemplified for Three Cases

—L. E. Hebl
Shell Petroleum Corp.

MENTION was made in the paper of the severity factors of automobiles. We have found this factor to be a useful tool in our work on detonation and wish particularly to draw this to the attention of automotive engineers, since an engine designed for a low severity factor can use to greater advantage the high research octane-number fuels often supplied. However, before citing three examples of its application, certain points in connection with its calculation need clarifying.

It is obvious that, since the depreciation on most fuels is not much greater than the errors of testing, the severity ratios obtained from the ratings on single fuels are, therefore, very inconsistent. However, the significance and reliability of the severity factor increases in proportion to the fuel sensitivity. Reliable values of the severity factor can be obtained by rating several sensitive fuels, adding together the depreciations obtained on the road and dividing the sum by the similar

Fuel Sensitivity in Cars

5		10		8		2		9		11		7		15		
Computed	Observed-Computed	Computed	Observed-Computed	Computed	Observed-Computed	Computed	Observed-Computed	Computed	Observed-Computed	Computed	Observed-Computed	Computed	Observed-Computed	Computed	Observed-Computed	
																r_1
11	−3	12	1	10	−5	8	−3	6	4	12	−2	10	3	2	−2	3.1
7	−2	8	2	6	4	6	−5	4	1	8	−3	7	−10	2	−2	2.8
9	1	10	−3	8	0	7	−3	5	2	10	3	8	−13	2	−3	2.9
4	4	4	−4	3	11	3	−10	2	−2	.....	.....	.....	.....	1	−9	4.4
5	−2	5	−5	4	−1	3	−6	3	−1	5	3	4	−17	1	−2	4.3
9	1	10	−3	8	0	7	−11	5	4	10	−2	8	−23	2	−5	6.2
17	−6	19	3	15	0	13	2	10	1	.....	.....	15	−7	.....	.....	3.4
16	−3	17	−3	14	−1	12	−3	9	3	18	1	14	−2	3	−5	2.6
16	−2	17	0	14	3	.....	.....	9	−3	.....	.....	14	−5	.....	.....	1.7
13	−1	14	0	11	−1	.....	.....	7	3	.....	.....	.....	.....	.....	.....	2.2
11	−2	12	−2	10	1	9	−6	6	4	13	−1	10	−5	2	−4	3.3
11	−3	12	−7	10	−2	9	3	6	−1	.....	.....	10	−5	2	3	2.3
9	−8	10	−1	8	−5	7	1	5	0	11	−8	8	8	2	2	3.9
16	−3	17	−1	14	0	12	−2	9	2	18	−3	14	−7	3	−2	2.7
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	—
15	−3	17	−6	13	−2	12	−1	9	−1	.....	.....	14	−6	3	1	3.0
.....	.....	.....	.....	.....	.....	7	1	.....	.....	10	−2	.....	.....	2	−2	1.3
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3.8
10	1	11	−1	9	−1	8	−5	6	0	11	1	9	−4	2	−2	2.2
13	−5	.....	.....	12	−2	.....	.....	.....	.....	.....	.....	12	−4	.....	.....	4.2
9	3	10	−6	8	−4	7	−7	5	2	10	0	.....	.....	2	−2	3.0
17	5	18	−4	15	−1	13	−13	10	3	.....	.....	.....	.....	.....	.....	4.4
.....	.....	.....	.....	17	−1	15	−5	11	9	23	−8	18	−13	.....	.....	5.9
22	2	24	2	19	2	17	0	13	−1	25	−5	20	−1	5	−2	3.1
2.4		2.4		2.3		4.0		2.1		2.7		6.7		2.5		3.4
−1.3		−2.0		−0.2		−3.8		+1.4		−1.9		−6.5		−2.2		

sum of the depreciations obtained in the A.S.T.M. test on the same fuels, the depreciation in both cases being measured from the research-method ratings. Table *A* gives an example of the procedure followed.

Table *A*—(Hebl Discussion). Example of Computation of Severity Factor; Tests Made in Car No. 15 at Uniontown

	Laboratory Ratings			Hill Ratings		Cross-Country Ratings	
Fuel	Research	A.S.T.M.	Sensitivity	Rating	Depreciation	Rating	Depreciation
12	113	80	33	92	21	90	23
7	86	72	14	79	7	73	13
5	79	65	14	67	12	67	12
	Totals		61		40		48

Severity Factors: 40/61 = 0.66 and 48/61 = 0.79

The importance of rating the same fuels under each test condition is obvious. The severity factor as computed in Table *A* will be found useful for analyzing data from tests carried out in the past; for instance, the results presented to the C.F.R. Committee by the Ethyl Gasoline Corp. early in 1932, and the Uniontown data. Three examples of its use in connection with tests are given, as follows:

Influence of Cylinder-Head Material on Engine Severity.—Fig. *A* illustrates the effect of aluminum cylinder-heads. The severity factors of the ten Uniontown cars having aluminum cylinder-heads were, on the average, one-third less than those of the twelve cars fitted with cast-iron cylinder-heads. However, the change in cylinder-head material was accompanied by other changes, such as in the thickness of the material, in combustion-chamber shape, and in compression ratio; and before it can be definitely settled how much the severity factor is affected by thermal conductivity, this factor should be changed by altering the material of the cylinder head, at the same time maintaining all other factors constant.

Effect of Atmospheric Temperature.—Fig. *B* shows the influence of air temperature on the severity factors of three different automobiles, from data obtained in our laboratory. At air temperatures of approximately 70 to 100 deg. fahr. these ratings matched those by the A.S.T.M. procedure, while at temperatures of approximately 10 deg. fahr. the ratings would match those by the research method.

Influence of Driving Conditions on Severity.—The special data shown in Table 6 of the paper, which were obtained at Uniontown under different driving conditions, are of particular interest in showing that ratings made on this hill are not unduly severe. The severity factors in Table *B* were obtained from these ratings.

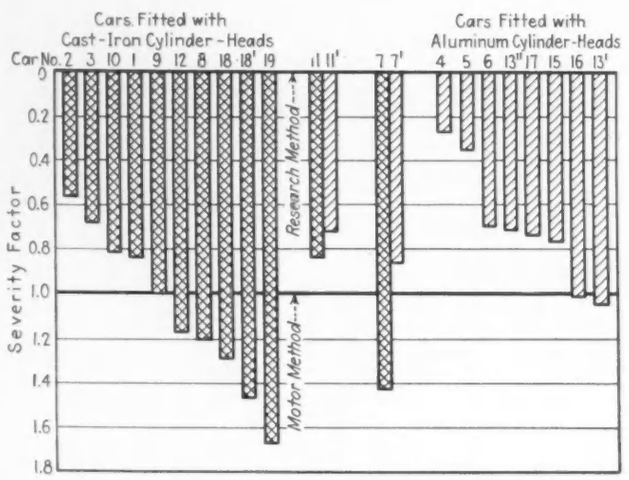

Cars Fitted with Cast-Iron Cylinder-Heads
Cars Fitted with Aluminum Cylinder-Heads
Car No. 2 3 10 1 9 12 8 18 18' 19 11 11' 7 7' 4 5 6 13" 17 15 16 13'
Severity Factor
0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8
Research Method
Motor Method

Fig. *A*—(Hebl Discussion) Effect of Aluminum Cylinder-Heads

Table *B*—(Hebl Discussion). Severity Factors Under Different Conditions

Car	Level-Road Acceleration from 10 M.P.H.	Hill Acceleration from 10 M.P.H.	Cross-Country High-Speed Driving
Ford No. 6.....	−0.51	0.33	0.53
Chrysler No. 15....	.68	.66	.79
Plymouth No. 8....	.63	1.07	2.38
Mean	0.27	0.69	1.23

These examples illustrate how the severity factor can be used for expressing the depreciation obtained with a given engine in terms of the depreciation between the two standardized test procedures. Indications are that the severity factor, besides giving a direct measure of the tendency of an engine to depreciate sensitive fuels, is fairly reliable.

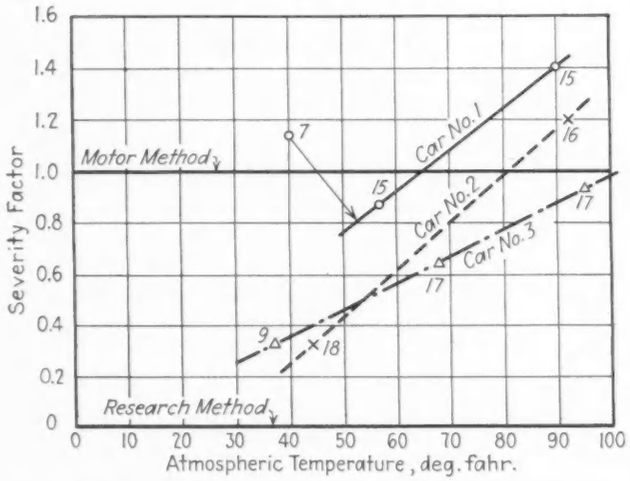


Fig. *B*—(Hebl Discussion) Influence of Air Temperature on the Severity Factors of Three Different Automobiles, from Laboratory Data

The chart indicates the total sensitivity of the fuels rated.

How Engine Conditions Vary Knocking Tendency

—**J. M. Campbell**
General Motors Corp.

SEVERAL speakers at this session have discussed the variations in knock ratings that are observed between different makes of cars and even between different cars of the same make. It might be pointed out that the magnitude of these variations may not be so disturbing as it may seem at first sight when it is recognized that these variations in knock rating from one car to another are all measured with respect to standard reference fuels A-3 and C-8 whose knocking characteristics are somewhat unlike those of the average commercial gasoline.

Although these reference fuels have certain desirable properties, particularly from the standpoint of stability in storage, their sensitivity to changes in engine conditions is such that they present a somewhat magnified picture of variations in knock ratings between different cars. On the other hand, if a representative commercial gasoline, such as is of necessity employed in the development of car engines, were used as a reference fuel, the variations in knock ratings between different cars might be expected to be very much reduced.

As was pointed out in the C.F.R. Report, knock ratings change with engine conditions because different fuels have different rates of change of knocking tendency with changes in engine conditions. The accompanying charts show two extreme cases of how knocking tendency may vary with engine conditions. Fig. *A* shows the effect of mixture ratio at 750 r.p.m. Here, mixture ratio is plotted on the horizontal axis and knockmeter reading on the vertical axis. At a mixture ratio of 14 to 1, gasoline *b*-1 was equal to a reference fuel of 80 octane number; and at a mixture ratio of 11 to 1, the same gasoline was equal in knocking tendency to a reference fuel of 74 octane number. Both gasolines knocked less at the rich mixture-ratios but, with increasing richness of mixture, the knock fell off more rapidly with the reference fuels.

Fig. *B* shows the effect of speed at constant mixture ratio; about 14 to 1. Engine speed is plotted on the horizontal axis against compression ratio for borderline knock on the vertical axis. At 600 r.p.m., gasoline *b*-1 was equal to a reference fuel of 82 octane number, and at 1500 r.p.m. gasoline *b*-1 was equal in knocking tendency to a reference fuel of 74 octane number. Both fuels decrease in knocking tendency with increasing speed as shown by the increase in compression ratio for borderline knock, but the knock falls off more rapidly with the reference fuel.

It seems quite probable that these two factors, mixture ratio and engine speed, contribute very largely to the variations in knock ratings among different cars inasmuch as road ratings are made over a wide range of mixture ratios and engine speeds. Incidentally, with respect to each of these two variables, the reference fuel appears to be the more "sensitive" fuel.

Variations in knock ratings with respect to the reference fuels naturally imply that some cars rate fuels lower than others. This has given rise to the concept of engine "severity" and "depreciation" of antiknock value in service tests. As a matter of fact, the data upon which these concepts are based do not indicate whether it is the average gasoline that "depreciates" or the reference fuel that "appreciates." Further-

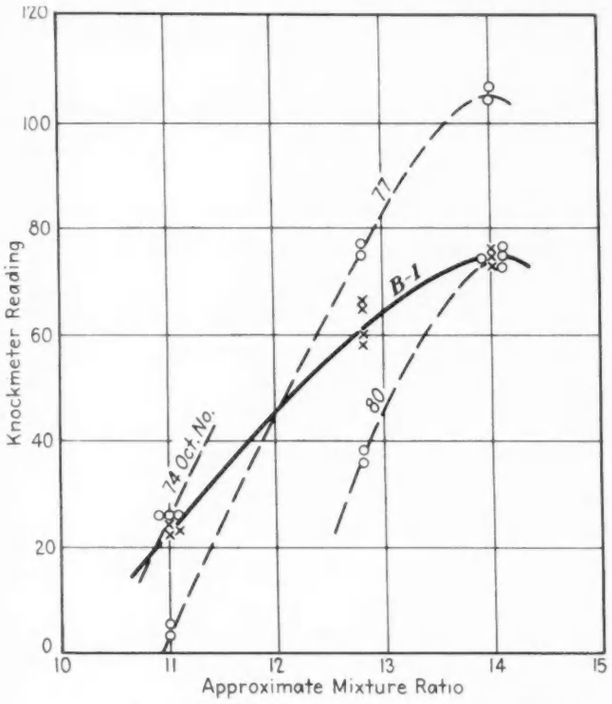


Fig. *A*—(Campbell Discussion) Effect of Mixture Ratio at 750 R.P.M.

The chart is for a single-cylinder, variable-compression engine having a 5.8 compression ratio. Spark, 30 deg. before top dead-center. Mixture temperature, 55 to 60 deg. fahr. Jacket temperature, 212 deg. fahr.

more, our conception of "depreciation" seems to depend upon the reference fuels used and upon the engine conditions used as a basis for comparison, as shown by Figs. *A* and *B*. If we start from lean mixtures, then gasoline *b*-1 "depreciates." If we start from rich mixtures which are representative, then the reference fuel appears to "depreciate" with respect to gasoline *b*-1. If we start from low speeds, then the gasoline *b*-1 appears to "depreciate" at high speeds. If we start from high speeds, then the reference fuel appears to "depreciate" at low speeds. Accordingly, the solution of the problem of designing engines so that they will not "depreciate" fuels appears to depend upon the reference fuels chosen and upon the engine conditions with respect to which "depreciation" is measured.

For example, suppose we measure "depreciation" with respect to the A.S.T.M. method of test and use reference fuels A-3 and C-8 as used in the Uniontown tests. We find that, in Car No. 2, commercial fuels generally knock less than the reference fuel of equivalent A.S.T.M. rating and, in Car No. 19, the same commercial fuels knock more than the reference fuel of equal A.S.T.M. rating. In other words, the test fuels appear to "appreciate" in Car No. 2 and to "depreciate" in Car No. 19. From this it might be concluded that, in order to eliminate "depreciation" in Car No. 19, the engine design should be changed to make the ratings conform with those obtained in Car No. 2.

On the other hand, if a commercial gasoline is used as a reference fuel, then fuels A-3 and C-8 will appear to "depreciate" in Car No. 2; since, in Car No. 2, they knock more than the new reference fuel of equivalent A.S.T.M. rating. The same fuels will then appear to "appreciate" in Car No. 19, since they will then knock less than the new reference fuel of equivalent A.S.T.M. rating. From this second series of tests the conclusion would be that Car No. 2 "depreciates" fuels and, in order to reduce depreciation, Car No. 2 should be changed to make the ratings conform to those obtained in Car No. 19. This is exactly opposite to the conclusion reached in the previous tests where a different reference fuel was used.

Stating the problem in another way, we are not sure whether our standard reference gasolines are "depreciated" in cars like Car No. 2, or whether commercial gasolines are "depreciated" in cars like Car No. 19.

Still another way to examine the same problem is to consider two different types of gasoline *a* and *b* which are equal by the A.S.T.M. method of knock rating. In one car, gasoline *a* knocks less than *b*; in another car, gasoline *b* knocks less than *a*. Which car is of the better design from the standpoint of utilization of antiknock value? The answer appears to be that the first car is better adapted to gasoline *a*, and the second car is better adapted to gasoline *b*.

Since engines are actually developed to use conventional types of gasolines rather than to use fuels similar to reference fuels A-3 and C-8, it may be preferable to choose a more representative type of gasoline for a reference fuel for measuring knocking characteristics. With such a reference fuel the matter of "appreciation" and "depreciation" of fuels in service would be expected to be reduced to insignificance for the large majority of commercial gasolines, and only a few exceptional types of fuels would show appreciable amounts of either "appreciation" or "depreciation." Very important to note, however, is the fact that the knock-testing procedure which would correlate all types of fuel with road performance would not be affected by such a change in reference fuels.

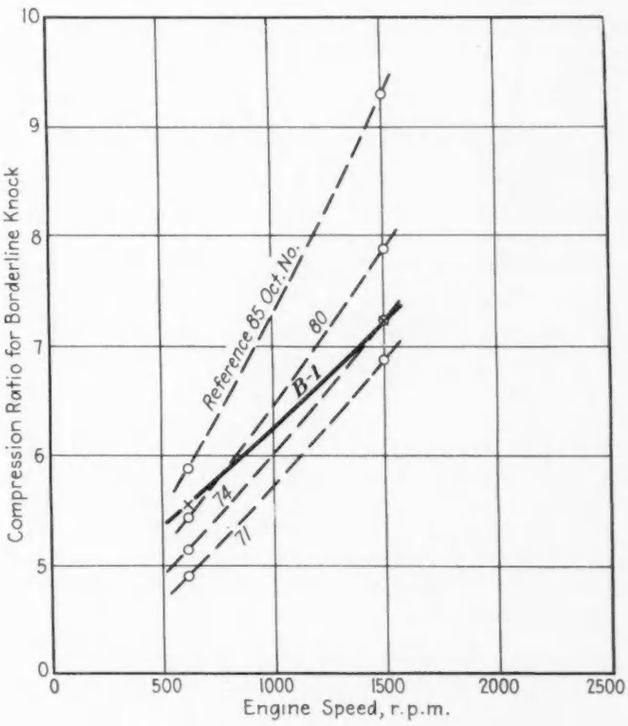


Fig. *B*—(Campbell Discussion) Effect of Speed at a Constant Mixture-Ratio of About 14 to 1

The chart is for a single-cylinder variable-compression engine using a mixture ratio for maximum power and a spark timing for maximum power. Mixture temperature, 60 deg. fahr. Jacket temperature, 212 deg. fahr.

A Designer-Manufacturer Viewpoint of Transport-Aircraft Needs

J. H. Kindelberger and J. L. Atwood
General Aviation Corporation

Part 1

By J. H. Kindelberger

ONE of the most essential points in the development of any airplane is the necessity for complete cooperation between the operator and the contractor in regard to necessary and desirable features to be incorporated, and this is particularly important for a commercial-transport airplane.

This coordination was carried through to a remarkably efficient culmination in the development of the Douglas transport for T.W.A.

Points discussed include arrangement of cabin and cockpit, seating facilities, upholstery, elimination of vibration, heating and ventilating, soundproofing, toilet facilities, lighting, vision and maintenance.

The care with which all these practical considerations were worked out is discussed, and special emphasis is laid on the important points of soundproofing and maintenance in which a remarkable degree of perfection has been attained.

This care and attention to details is well worthwhile and only in this manner can a really successful transport be designed incorporating all the technical and practical knowledge of the operator, manufacturer and other specialists who assist in perfecting the various installations.

IT is indeed a happy combination when a user or operator of any product cooperates intelligently and wholeheartedly with a thoroughly experienced manufacturer in the development of new equipment. This is particularly true in the design of equipment for the air-transport field, since the relative youth of the air-transportation industry and the keen competition therein have prevented the accumulation of data that could be considered standard or reliable and sufficiently certain to be used by a manufacturer acting independently as a basis for the design of new equipment. It is, therefore, essential that an operator contemplating new equipment be prepared to specify all of the requirements as to performance, capacity, maintenance, passenger comfort, arrangement and equipment, as will combine to produce an airplane satisfactory for his needs. It must also be borne in mind that such new equipment must be predicated upon the needs of the times two years in advance, as the average transport airplane requires a year for the production of the experimental article and an additional year for testing and preparing for quantity production.

The Douglas "DC-2" transport is an excellent example of the result of such cooperation, and much credit for the general suitability of the airplane for the purpose intended is due to Jack Frye, who, with a selected group of T.W.A. pilots, inspected the various mockups and made many helpful suggestions and criticisms; to Walter Hamilton, who supervised the design from a maintenance standpoint; and to D. W. Tomlinson, who supervised the long series of acceptance and flight tests.

The requirements set up by T.W.A. for this airplane were

[This paper was presented at the Annual Meeting of the Society, Detroit, Jan. 16, 1935.]

based upon years of experience in the operation of a transcontinental airline from Los Angeles to New York. This line, crossing the country diagonally, encounters every conceivable type of topography and climatic condition. Therefore, an airplane based upon the requirements of T.W.A. is suitable not only for any line in this country, but for practically any condition of service likely to be encountered in airline operation anywhere. As an example of the detail in which the operator's requirements were furnished the contractor in this particular case, the section of the specification pertaining to maintenance is stated in the Appendix.

The engines specified must be of a type already in successful operation, as the use of engine manufacturers' hopeful promises as a basis for the design of new equipment is extremely hazardous. The promised increases in power and altitude performance of existing types and the successful completion of new types of engines have a way of remaining with prosperity, just around the corner. It is, of course, necessary and wise to consider the installation of improved powerplants when and if developed, and to make such provision as is consistent with the design of the airplane for their future installation; but, on safety, the performance requirements must be set up around existing powerplants.

From the standpoint of the operator, the airplane must be as fast as is consistent with other requirements, as the principal selling point of air transportation is speed. The other requirements that determine general design are landing speed, range with a given payload, performance at altitude with one engine out, number of passengers, weight and volumetric requirements of mail and express. With this information an accurate weight estimate can be made and the general characteristics and dimensions of the airplane determined.

It is perfectly possible, using average values and criteria, to produce a reasonably good airplane without wind-tunnel studies. However, it is not believed that the ultimate efficiency of any aerodynamic combination can be reached without a complete study in the wind tunnel at a scale that will permit the effect of even minor changes and variations to be determined. Again using the DC-2 as an example, the wind-tunnel tests started with the wing alone, three types being tested; then, combinations of wing and fuselage with various fillets and fairings until the drag of the combined parts appeared to be an absolute minimum. The same scheme was used for the nacelles, several types of which were tested with the best fuselage and wing combination, as well as the tail surfaces and ailerons. The model in this case was one-eleventh full-scale. The control surfaces were perfectly balanced and mounted on ball bearings and it was possible to make actual tests on the effectiveness of the trimming tabs on the various surfaces.

Passenger Comfort Important

A factor which is almost as important as performance in determining the success and popularity of air transport for passenger work is the degree to which passenger comfort is provided. The major factors which affect the comfort of the passengers are room, seats, vibration, heating, ventilation, and noise. The factors of less importance are toilet facilities, lighting, provision for serving meals, and vision. These will be discussed in the order named.

It is essential that the cabin be sufficiently large to provide for seats of ample size, an aisle of sufficient width so that passengers walking up and down will not disturb passengers in the seats, and high enough so that a tall man with a hat on can walk throughout its length without stooping. It is also desirable to have the cabin structure as free from structural members as possible, as there is a distinct dislike on the part of the passengers to climb over or through structural members. This objection does not seem to be so forceful in the case of such cabin arrangements which provide compartments for seating groups of passengers. The use of compartment-type planes will probably increase due to the demand on the part of transport operators for airplanes with sleeping accommodations. A width of at least 24 in. must be allowed for each seat, and there should be at least an inch clearance between the seat and the inner lining of the cabin. The aisle should not be less than 16 in. wide. This means that the minimum width of a cabin for seating two passengers is approximately 5 ft 6 in., and an additional 25 in. will be necessary for each additional passenger added across the width of the plane. A very satisfactory height for the cabin at the aisle is 6 ft. 3 in. It is not essential that the height over the seats be such as to permit of standing erect at that point, but the use of members over the seats that may be struck by a passenger rising should be avoided.

Type and Design of Seats

The seat itself, being the point of contact of the passenger with the plane, cannot be given too much attention. Inasmuch as an air traveler is seated for long periods of time, as much as 5 to 6 hr. without much opportunity to move about, and since in many cases he will occupy this seat with only slight interruptions for as long as 18 to 20 hr. in transcontinental flight, every factor contributing to his comfort must be given consideration. It is obvious that provision must be made for reclining. It is not enough to provide simply a back which may be lowered, as the angle between the seat itself and the seat back is of great importance. It should, therefore, be possible to adjust the angle of the seat proper to the floor, as well as the angle of the back to the seat so that any reasonable combination can be secured.

It is considered very desirable by the operators to provide seats which are reversible. It is practically impossible to make a swiveling seat, as the clearance necessary to rotate the rectangular form of the seat bottom is never available. As in the case of the old-type street-car seat, the same idea can be carried out by flopping the back of the seat over, since it can be located so that the top of the seat in the forward position becomes the bottom of the seat when facing aft. This arrangement permits passengers to face each other for conversation or card playing but, while quite desirable, is not believed to be absolutely necessary. I have flown on many cross-country trips in the Douglas DC-2, in which this feature has been provided; but, in perhaps 200 hr. of travel, I have never seen a seat reversed except as a demonstration. The seats must be provided with the foregoing adjustment and they must be arranged so that it is possible for the passenger to make adjustments to suit himself. They must, therefore, be very simple and must not require a great deal of force to operate them.

It is very desirable to incorporate in the design of any seat some form of foot rest for the passenger. This could readily take the form of a deck-chair type of apron or could be a shelf attached to the seat ahead. In any case, it should be easily operated, light, and adjustable. The cushions on the seat bottom should be deep and provided with springs, as well as padding. A good job of upholstery in the chair will go a long way toward smoothing the unavoidable bumps on

landing and take-off and in the air, and will greatly add to the comfort of the passengers.

The seats should not be attached directly to the structure of the airplane, as it is impossible to eliminate all the vibration of the powerplant, and it is very helpful to attach the seat so that it does not make direct metallic contact with the structure, but is attached by means of suitable rubber shock-absorbing connections. These connections should be free floating; but at the same time they must provide sufficient strength to take care of the loads imposed upon them in case of a crash, as the loads coming from a passenger seat-belt are relatively high. The belt itself must be wide enough to prevent too localized a load on the person being restrained by its use, and must be quickly and easily adjustable in a manner so simple that the average person will be able to take care of it unaided.

Vibration

It is impossible to produce a powerplant which will not vibrate. The vibration as transmitted through the structure to the passenger is very distressing, and everything should be done to stop the transmission of that vibration. The logical point to apply damping means is at the attachment of the powerplant to the structure, and several types of rubber-insulated connections have been developed that contribute very greatly to reduce the vibration. The reduction of vibration is important not only because of the passengers' comfort, but also because of its effect upon the structure itself. The use of a vibration-absorbing floor, which in turn is attached to the structure so that it is free floating, will aid considerably in this connection. This can be accomplished by the use of rubber or felt between the floor and the structure. A floor which is very light and at the same time cheap and simple is a sandwich of balsa wood between very thin face-plies of birch. This type of floor was first used for weight saving by the author in one of the original Martin bombers, and has been found to be very satisfactory even when used in seaplane construction. It has the advantage of not only being structurally efficient, but is excellent in its sound and vibration-damping qualities.

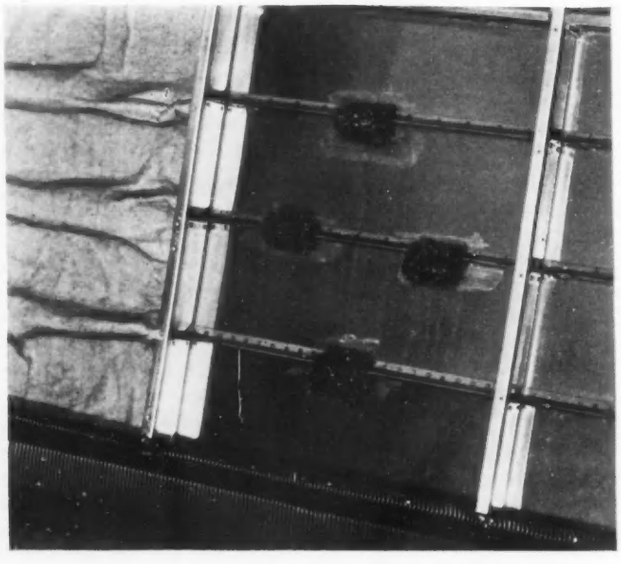


Fig. 1—An Example of Cabin-Wall Soundproofing

Heating and Ventilation

The heating and ventilation of airplanes have been sadly neglected and are matters of supreme importance. In order to provide passengers, particularly at high altitudes, with a satisfactory supply of air, it is desirable to change the air in the cabin every minute and it must be changed at intervals not greater than two minutes. This requires that a large volume of air be handled and heated, as temperatures of minus 20 deg. fahr. are frequently encountered at altitudes at which modern transports fly in winter. It is necessary that air be introduced so as to prevent direct drafts and that it should be removed quietly and uniformly. The simplest manner of achieving this result is, as in the case of theaters, to introduce the air under each seat. This can be accomplished by running ducts down each side of the cabin. It is necessary to design such ducts and outlets with great care in order that the air will be discharged at a fairly uniform rate throughout the length of the cabin. It is also considered necessary to provide a cold-air supply for each passenger. This has been customary in the past simply by using a rotatable scoop on the outside of the plane which directed a jet of air into the passenger's face when it was rotated toward him. This is quite satisfactory for getting the air to the passenger, but is impossible in the case of a plane which is supposed to be quiet, as the opening of such ventilators raises the noise level very appreciably. It is necessary then to provide additional ducts about the passenger seat to conduct this cold air to each passenger seat. This feature is considered necessary as a prevention of air sickness.

It is believed that, with further improvements in direct ventilation, the individual cold-air supply can be dispensed with. In order that the air may be pure and clean and free from odors, it is necessary that the air supply be as far as possible from the engine, preferably ahead of the engine. On a two-engined plane, the ideal place for the air inlet is the front of the fuselage, where the impact pressure is sufficiently great to provide sufficient energy for the proper circulation of the air.

The customary method of providing cabin heating by installing a stove around a section of the exhaust pipe, through which the air is forced and heated, is not only unsatisfactory in that it does inevitably introduce air containing the odor of burned oil from the engine but it is positively dangerous. Such stoves have been the cause of several serious situations when leaks in the exhaust pipe around which they are placed permitted the exhaust fumes containing carbon monoxide to be introduced directly into the cabin.

It is believed that the best method of conducting the heat from the exhaust pipe to the cabin is by means of a steam heating-system. This has been accomplished very satisfactorily in one instance by the use of a flash-type boiler, the steam from which is carried to a standard airplane cartridge-type radiator under the cabin floor and from the radiator to condensers from which the condensed steam flows as water back to the boiler. With such a system the heat is readily transmitted and there is no possibility whatever of any fumes being carried into the cabin. By a proper arrangement of valves, it is possible with such an arrangement to deflect a sufficient amount of the incoming air through the radiators to maintain any desired degree of heat in the cabin. In the instance mentioned, this diffusing valve is operated by means of an electrically driven gearbox directed by a thermostat in the cabin.

It is believed that equally satisfactory results could be ob-

tained by using a manually controlled valve operated from the co-pilot's seat and connected with a distant-reading thermostat which would give the co-pilot the temperature of the cabin and make it unnecessary for him periodically to check it. Such an arrangement requires careful design and test to make it function satisfactorily, and every installation will of necessity have to be worked out to suit the conditions involved. However, it is extremely encouraging to find for the first time that this type of system can be made to operate satisfactorily. A temperature of 70 deg. fahr. has been maintained in the cabin while the outside temperature was minus 10 deg. fahr.

Soundproofing

By far the most important point contributed to the comfort of the passenger is the reduction of noise. The science of soundproofing is a job in itself and is very little understood by the average airplane designer. A great amount of research and development along the lines of sound reduction has been done by the Sperry Corp., and Dr. Stephen J. Zand, of this corporation, deserves great credit for his work along these lines. In the original design of an airplane it is exceedingly important that the designer consult with an acoustical expert, and it is very possible to produce a satisfactory sound level in the cabin with the expenditure of half the weight if the acoustical requirements are kept in mind throughout the design.

The source of the greatest noise at high speed is the propeller; at cruising speed, it is equally propeller and engine. Inasmuch as the propeller noises increase very rapidly with the tip speed, it is very desirable to use a propeller satisfactory as to other conditions but with as low a tip speed as possible. An English engineer stated, after a thorough investigation of propeller noises, that a reduction of 10 decibels can be obtained for each 100 ft. per sec. reduction of tip speed. It is obvious, therefore, that geared three-bladed propellers will contribute greatly to the reduction of noise.

Another matter of paramount importance is the location of the exhaust. This should be kept as far away from the cabin as possible and, in the case of a low-wing monoplane, should be discharged under the wing on the outboard side of the nacelle, as the intervening wing structure contributes very greatly to the damping of noises without adding appreciably to the weight. The windows permit a great deal of transmission of sound to the cabin as it is impossible to apply any ordinary soundproofing means over these areas. A simple method of preventing the window from acting directly as a diaphragm and which greatly reduces the amount of sound transmitted is to mount the window in rubber in such a manner that there is a rubber web around the periphery of the window so that the window is practically free floating and not clamped in a metallic channel with rubber packing, as is customary.

Resistance to sound transmission has been shown to be in direct proportion to the mass of the sound-deadening wall. It is obvious therefore that weight, being so vital a consideration in an airplane, is impracticable to prevent sound transmission directly, although every possible precaution should be taken to provide against the penetration of sound from the outside. It is essential that panels be braced to prevent their drumming as a diaphragm, and that partitions be rigid. Inasmuch as it is not economical to produce a satisfactory reduction in the volume of sound by preventing its penetration,

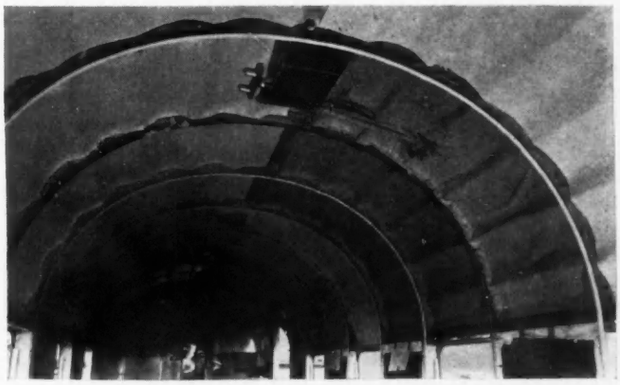


Fig. 2—Showing the Method of Soundproofing a Cabin Ceiling

it is necessary that everything possible be done to absorb the sound which will penetrate. There are various methods of doing this and the manufacturers of heat insulation claim generally that their product is equally as good as soundproofing. This has been proved by laboratory tests to be not necessarily true. Furthermore, materials which absorb noises of high frequency are not particularly effective against the low-frequency noises. It is, therefore, obvious that a great deal of research is necessary to determine the best material and the best location and arrangement of the material for any particular condition.

It is also impossible to design completely the soundproofing installation of an airplane before flight. It is essential that the airplane be flown at various speeds and that the sound conditions be measured and plotted in order that a basis may be determined from which to plan the installation of soundproofing. The most efficient soundproofing arrangement, not only from the standpoint of noise reduction, but from a practical standpoint of the lining of a cabin that is both attractive and durable, has been invented and patented by Dr. Zand and was used in the Douglas transport. See Figs. 1 to 4. It consists of a lining of doped fabric, behind which, and in contact with which, is a thin layer of a special felt. The energy in the sound waves causes the tautly stressed fabric to vibrate and the vibration is instantly damped by the felt, which in itself is very efficient in the absorption of sound. It is necessary, further, to avoid the use of metallic linings or linings of wood which will reflect the sound and cause reverberation.

A satisfactory method of providing a durable lining for the lower part of the cabin, where it is apt to be kicked and scuffed, is the use of a sandwich of balsa wood between thin layers of duralumin. The outside dural sheet, that is, the sheet away from the inside of the cabin, should be perforated in order that the sound-absorption qualities of the material between the duralumin sheets may be increased. For those interested in the problem of soundproofing an airplane, it is suggested that the paper[1] "Noise Reduction in Cabin Airplanes," by Preston R. Bassett and Stephen J. Zand, and the paper[2] "Acoustics and the Airplane," by Stephen J. Zand, be read.

An excerpt from a recent letter from Dr. Zand is quoted, as follows:

"I am taking the liberty of giving you my frank opinion of what can be expected in increasing the comfort of passengers in the next few years.

[1] See *Transactions of the American Society of Mechanical Engineers*, vol. 56, 1934, AER-56-2, p. 49.
[2] See S.A.E. JOURNAL, February, 1934, p. 41.

"Having brought down the noise level of airplanes to about 70 decibels for an expenditure of about 10 to 12 lb. per passenger, we have reached a figure where a further decrease in noise level would cost a tremendous amount of weight. With present methods, if the weight should be doubled, a decrease of about 4 decibels could be expected, which we believe is hardly worthwhile. We are approaching the stage of diminishing returns, due to the fact that the insulating value of the material is only proportional to the logarithm of the weight. However, with the introduction of multi-cylinders, the exhaust frequency becomes higher, and there a certain gain can be expected for the reason that high-frequency sounds are more easily absorbed than low frequencies. It is also possible that certain types of airplanes will be developed where the tip speed of the propeller will not exceed 600 ft. per sec. and then an appreciable reduction, say, to 60 decibels in the cabin with the same figure for weight per passenger, can reasonably be expected. Maybe, but I doubt it, there will be someone who will invent a perfect muffler and a silent propeller and apply *both* to an airplane. I also believe that, with the possibility of using an exhaust-driven supercharger, certain improvements in cabin comfort can be obtained, but these will be very slight."

Rules for Soundproofing

The following rules are quoted from the paper "Noise Reduction in Cabin Airplanes."

"(1) The engines should be mounted as far ahead of and as far away from the cabin as practical, consistent with good aerodynamic efficiency

"(2) Three-blade or four-blade slow-moving propellers are better acoustically than two-blade fast-moving propellers

"(3) Great care must be exercised to prevent the transmission of vibration to the cabin by solid conduction; thus, vibration control through the use of properly designed vibration insulators is imperative

"(4) Double windows are at present of no value in an airplane cabin

"(5) The cargo compartment should be located preferably in such a position as to form a barrier to the source of noise

"(6) Exhaust manifolds should be located at a point as far removed from the cabin as possible, and either wing or nacelle should be used as a sound shadow between exhaust and the cabin

"(7) The cabin should be as tight as possible, as small leaks will offset the value of elaborate acoustical treatment

"(8) Ventilating and heating systems should be made quiet by filtering out the noise before admitting the air to the cabin

"(9) The inside of the cabin should be covered with a material which will absorb as much noise as possible; the material should be particularly effective in the absorption of the predominant frequency of that particular airplane

"(10) All accessories, such as lamp shades, ash trays, curtain rods, etc., should be fastened very securely to the structure to prevent acting as localized sound sources

"(11) Avoid the use of large unsupported panels of thin section, as they act as loud-speaker diaphragms

"(12) Blanket materials which will pack are not suitable and should be avoided"

Fig. 3—Illustration of Details of Bulkhead Sound-Insulation

The toilet facilities in an airplane must receive a great deal of attention. They, of course, must be convenient and comfortable. The type of toilet used on most planes in the past, which consists simply of a chute open to the air below, is not permitted to be used at the present time for obvious reasons. It is necessary, therefore, to provide a toilet which will not have the foregoing objections and still be satisfactory. After a considerable amount of investigation and study, it is believed that the best arrangement is one consisting of a metal container with a waterproof-paper liner of sufficient capacity in which is used one of the many chemical preparations on the market for such purposes. It is essential in the design of such equipment that it be possible to change the container very quickly and simply, as any factor which adds to the time a plane is on the ground is of vital importance. There are several satisfactory washbasins on the market. It is necessary in providing for the water supply to place the tank in such a manner that it can be filled readily from the outside of the airplane and yet be in such a location that it is not likely to freeze in sub-zero weather. Too much attention cannot be given the careful and attractive treatment of the lavatory and toilet equipment.

The lighting of the cabin must be very carefully worked out. It has been the observation of the writer that very few people use the lighting system. The average passenger usually settles himself down to sleep about the time it begins to get dark. It is essential that lighting facilities be provided, however, and that they be so arranged that a reading light used by one passenger will not disturb the adjacent passengers, who probably desire to sleep. A simple arrangement is to provide a light so masked that when lit it will throw a beam of light directly on the paper or magazine of the person using it, but which will be confined to that area.

Provision for passenger vision is of less importance than it was once considered; but, other things being equal, it is worthy of consideration. The ideal airplane from the standpoint of passenger vision would be a high-wing monoplane with two rows of seats only. This type of airplane is objec-

tionable for other reasons and it is believed that in the future very little attention will be given to providing for vision for the passenger, as most passengers are habitual travelers and in most cases seldom more than glance out the window, except for the few minutes during take-off and landing.

Due to the fact that airplanes are flying across the continent on very tight schedules and since it would be extremely inefficient to stop the plane long enough for the passengers to eat on the ground, it is necessary that provision be made for providing the passengers with meals while in flight. At the present time, it is customary to provide each passenger with a tray which can be attached to the seat and then to give him a sort of picnic lunch in a box. This arrangement is not bad for the first few trips, but becomes very tiresome to the seasoned traveler, who knows exactly what is going to be in the box before he opens it. It is believed that on newer equipment it will be necessary to provide some means of furnishing hot meals while in flight. Several companies are believed to have this matter under consideration at the present time.

Pilots' Cockpit and Controls

Assuming that the flying characteristics of an airplane are satisfactory, the most important point in determining the popularity of the airplane with the pilots is the pilot's cockpit. This is perhaps the most difficult section of any multi-engined airplane to work out in a satisfactory manner. Not only because of the complex nature of the installation, but because no two pilots will ever agree on what makes the perfect cockpit.

On a twin-engine airplane of modern type, there are sixteen controls for the powerplant alone. The flying controls, landing gear, brake, and automatic pilot, also total sixteen. This means that there are thirty-two individual controls which must be installed so as to be convenient to reach and operate, and yet not in any way interfere with the pilot or co-pilot. There are also, in addition to an automatic-pilot installation, eleven flight-control instruments. See Fig. 5. The problem of arranging all of these controls, in addition to some twenty switches and the radio installation, in such a limited space, is extremely difficult, and such an installation can be developed only by cut-and-try methods in a mockup.

The pilot's cockpit must be provided with satisfactory windows which can be opened or closed in flight and they must be designed so that they can be opened even with ice forming on the outside. They must also be placed so as to be free from reflections from the inside of the cockpit, as well as the outside. A method developed by the writer for designing such a window installation is to use mirrors in the mockup in the place of windows. By sitting in the pilot's seat and looking in the mirrors, it is obvious at once what part of the cockpit will be reflected. It is then possible to change the mirror so that none of the lighted portion of the cockpit will be reflected and then, by painting that portion which is reflected black or a dull green, one can be assured that there will be no internal reflection. The reflections of outside lights, such as boundary lights of an airport when coming in for a landing, can be determined by replacing the mirror with plain glass and, in pitch darkness, using a flashlight around the side of the airplane, again changing angles until no reflections are seen. This frequently requires several back-checks of mirrors and glass until the best compromise is obtained.

The pilot's seat should be given a great deal of attention. It should be well upholstered, adjustable vertically and as to angle of back, and provided with arms. The inside arm, of course, must be designed so that it can be swung out of the way when getting into or out of the seat. Further, all the controls must be located and designed so that the pilot or co-pilot will not bump them when moving into or out of his seat or in and around the cockpit. It is essential that the instrument board be very carefully designed and balanced. It must be mounted in shock absorbers so that it will float free and not be affected by the vibration of the airplane. Inasmuch as no two people will ever agree on what the best arrangement is for an instrument board, an arbitrary arrangement of instruments which seems to be as satisfactory as any is to place the automatic pilot in the center of the top of the board and locate the flight instruments, as well as the supercharger pressure-gage and tachometer, in front of the pilot's seat. The secondary powerplant instruments, etc., can be located in front of the co-pilot's seat. In any modern airplane it is necessary to consider the installation of an automatic pilot and it is almost impossible to make a satisfactory installation of this device unless the entire control system and instrument-board arrangement is built around it.

As will be noted in the Appendix, on maintenance requirements, the time element is given primary importance. The reason for this is not only in saving costs in the maintenance of the airplane, but to save time on the ground. Certain operations must be performed every time an airplane lands, and these operations must be done with a minimum number of people. The ground inspection which is given the airplane at every station must be completed in 10 min. and it is, therefore, necessary that every part of the airplane be readily inspectable and that any part which might have to be changed at the station be arranged for very quick handling. This is

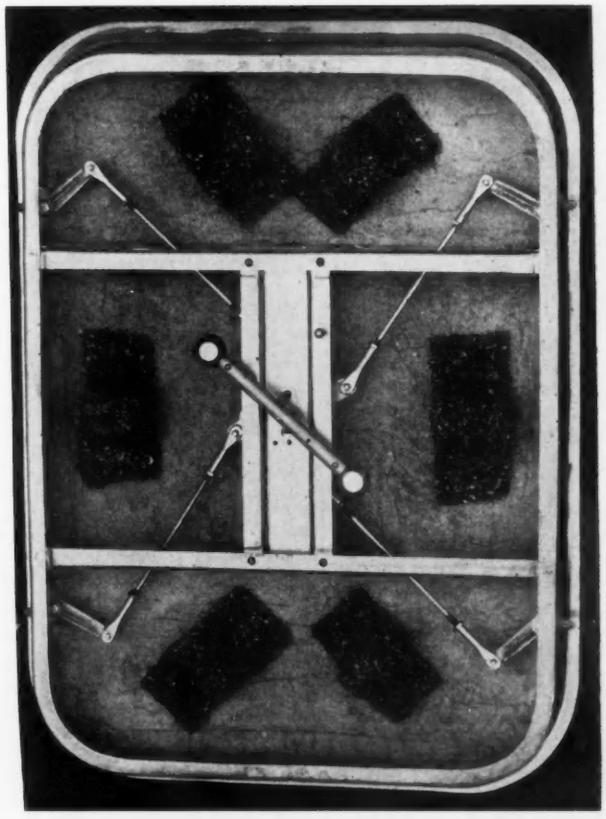


Fig. 4—Illustrating How a Cabin Door Is Soundproofed

very difficult of accomplishment unless the idea is kept in mind throughout the design of the airplane and its detail parts.

It is also essential that the provision for filling fuel tanks be given due attention, also for the reason that hundreds of gallons of fuel have to be dumped into the tanks in a very few minutes. It is necessary that the opening to the fuel tanks be not less than 3 in. in diameter, and that it be designed to take the impact of a solid stream of gasoline from a nozzle of this size. As an example of what can be done along these lines, the powerplant on the DC-2 airplane is designed so that it is possible to change the complete powerplant, propeller, engine, and all accessories, and replace it with another complete powerplant in 40 min. This means that an airplane arriving at a station with powerplant trouble will not be delayed greatly by the necessity for installing a new powerplant. The engine change on an airplane of ordinary type would consume from 4 to 8 hr.

In view of the foregoing, it is obvious that the modern transport airplane has become an exceedingly complex vehicle. From the standpoint of the designer and manufacturer it is essential that, in attempting to accomplish all the things demanded and desired by the operator, the idea of costs be watched very carefully. Throughout the structure, every piece must be designed so that it is capable of being produced in quantity as stampings or forgings. Of primary importance is the study of the location of rivets, as a rivet that is easily accessible can be driven in a few minutes, while rivets that are difficult to reach have taken as long as 2 hr. each. To produce the cheapest combination in any of the various units, it is essential not only to watch the design carefully and constantly throughout the work in the drafting room, but to follow it in the shop and to maintain constant cooperation with the engineering department and the shop in order that difficult operations may be eliminated or changed by redesign.

Appendix

Maintenance requirements extracted from the T.W.A. specification around which the Douglas DC-2 was designed.

(1) *Landing Gear.*—(*a*) It shall be possible for two men to change an assembled tire, tube and wheel in 10 min.

(*b*) It shall be possible for one man to change the assembled tail wheel, including a tire and tube, in 5 min.

(*c*) The shock-absorber system shall be inspectable for leaks and fluid quantity, without removing the cowling, by one man in 5 min. per airplane

(*d*) If hydraulic brakes are used, it shall be possible for one man to check the fluid level in all tanks, replenish, and close the job in 2 min.

(*e*) If cable control on brakes is used, all pulleys and clevises shall be inspectable and adjustable by one man in 3 min.

(*f*) If hydraulic retracting mechanism is used in connection with the landing gear, it shall be possible for one man to check the fluid levels in all tanks, replenish, and close the job in 2 min.

(*g*) All landing-gear bushings shall be easily replaceable and accessible for greasing and oiling. It shall be possible for one man to grease the landing gear in 1 min. It shall be possible for two men to replace all landing-gear bushings in 3 hr.

(*h*) The tail wheel and its shock absorbing mechanism shall be inspectable from the side or rear, and it shall be possible for one man to make this inspection and grease the complete assembly in 3 min.

(*i*) Landing-gear and tail-wheel jackpads shall be located so that they can be used when a tire is flat

(*j*) The retractable landing gear shall be completely inspectable in the down position by one man in 2 min., and shall be capable of being locked in the down position to permit operation of the airplane with the retracting mechanism inoperative or absent. For this purpose a jury strut will be satisfactory, if necessary. The complete landing gear shall be removable and replaceable by two men in 2 hr.

(*k*) Provision shall be made for jacking up the airplane, permitting operation of the landing gear up and down This operation shall take two men not longer than 30 min.

(*l*) Brakes shall be adjustable, without removing the cowling or other parts of the landing gear

(*m*) It shall be possible to remove and replace the complete landing-gear shock-units by one man in 1 hr.

(2) *Powerplant and Nacelles.*—(*a*) It shall be possible for three men to remove and replace the entire powerplant nacelles, consisting of the nacelle ahead of the firewall, the engine, the oil tank and oil lines, the ring cowl, the propeller, etc., in 30 min.

(*b*) The exhaust manifold shall be removable and replaceable in sections without demounting the other sections. Any one section shall be removable and replaceable by one man in 10 min.

(*c*) The oil-tank drain-plug shall be removable by one man in 30 sec.

(*d*) The engine cowl complete, including the anti-drag ring, shall be removable and replaceable by one man in 5 min.

(*e*) It shall be possible for one man to inspect the engine throttle and the altitude and spark controls on the nacelles in 6 min. These controls shall be completely removable and replaceable by two men in 1 hr.

(*f*) There shall be sufficient clearance adjacent to the starter to permit its removal and replacement by one man in 10 min.

(*g*) There shall be sufficient clearance adjacent to the generator to permit its removal and replacement by one man in 10 min.

(*h*) There shall be sufficient clearance adjacent to the carburetor and hot spot to permit its removal and replacement by one man in 20 min.

(*i*) There shall be sufficient clearance adjacent to the magneto to permit removal and replacement of the breaker-point assembly and distributor-block radio-covers by one man in 5 min.

(3) *Fuel System.*—(*a*) Any fuel-system line shall be completely removable by one man in 15 min.

(*b*) Each fuel tank shall be independently removable by two men in 30 min.

(*c*) All fuel strainers shall be opened, drained, closed and safetied by one man in 3 min.

(*d*) It shall be possible to remove and replace the wobble pump and the selector valves when the tanks are dry by one man in 1 hr. 30 min.

(*e*) The complete fuel system shall be inspectable by one man in 15 min.

(4) *Oil System.*—(*a*) It shall be possible to remove and replace the oil tank by one man in 15 min.
(*b*) The engine oil-strainer and sump plugs shall be removable and replaceable by one man in 2 min.
(*c*) The oil system shall be inspectable by one man in 2 min.

(5) *Cockpit.*—(*a*) The instrument board shall be inspectable from the rear by one man in 2 min. The flying instrument-panel shall be completely removable by one man in 25 min., exclusive of the automatic pilot
(*b*) All pilot's controls shall be accessible and provided with adjustable stops, and inspectable by one man in 3 min. All controls shall be readily accessible and replaceable. Piping, pushrods, cables, etc., shall be removable without dismantling other parts
(*c*) It shall be possible to inspect, remove and replace the rudder pedal assembly by one man in 1 hr.

(6) *Cabin Interior.*—(*a*) All passenger seats shall be identical and removable by one man in 2 min. each
(*b*) All cabin inspection panels and doors shall be readily accessible
(*c*) Complete servicing of the washroom and buffet shall be accomplishable by one man in 5 min., including filling all water tanks and thermos bottles and scrubbing the washroom floor and the toilet
(*d*) Each cabin window shall be replaceable by one man in 20 min.
(*e*) The curtains shall be installed to permit their removal and replacement by one man in 1 min. per window
(*f*) It shall be possible for two men to remove the passenger-cabin floor for control inspection and to replace it in 10 min.

(7) *Electrical and Radio.*—(*a*) The battery shall be accessible so that it can be inspected and watered in place by one man in 3 min., or can be completely replaced by one man in 4 min.
(*b*) The voltage-regulator control-box shall be accessible so that it can be replaced by one man in 2 min.
(*c*) The short-wave transmitter, the short-wave receiver and the long-wave receiver, shall be removable and replaceable by one man in 3 min. each
(*d*) The radio-receiving dynamotors shall be removable and replaceable by one man in 3 min.
(*e*) The engine-driven dynamotor-solenoid shall be easily accessible, and removable and replaceable by one man in 3 min.
(*f*) The radio antenna mast shall be capable of being retracted and replaced in position by one man in 2 min.
(*g*) Landing lights shall be accessible from the rear side. Bulbs shall be replaced by one man in 3 min.
(*h*) Fuses, except those in the battery compartment in the wing, shall be replaceable in flight by one man using one hand
(*i*) The nose cowl housing the radio equipment shall be capable of being removed and replaced in position by one man in 1 min.

(8) *General.*—(*a*) Each control surface (aileron, elevator, rudder, flaps) shall be replaceable by two men in 10 min. each
(*b*) The stabilizer shall be strong enough so that men can move the airplane into and out of the hangar regularly by pushing on it
(*c*) All controls and moving parts in the fuselage tail-section shall be accessible for inspection and maintenance by one man in 1 min.

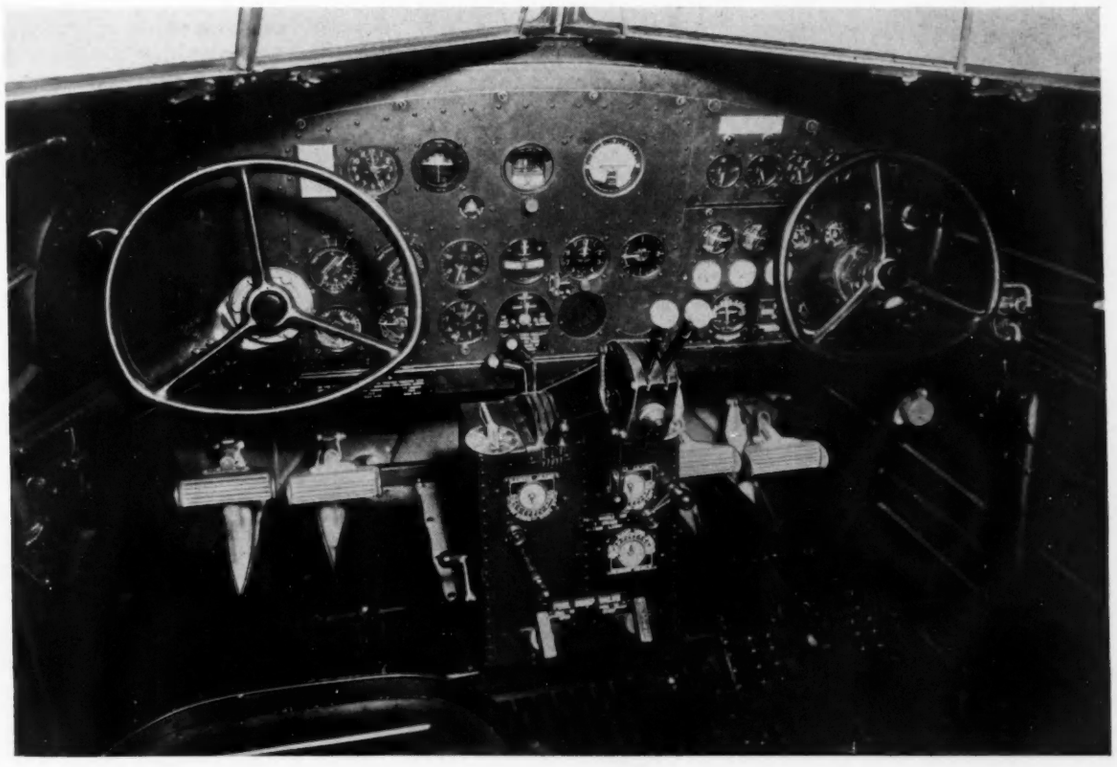


Fig. 5—Showing the Pilots' Cockpit and the Arrangement of the Controls and Instruments

(*d*) Steps, doors, handles and reinforcements shall be strong enough to withstand service abuse and shall be approved as to location by the buyer

(*e*) Closed members and blind rivets shall be avoided as much as possible throughout the structure

(*f*) Removal and replacement of flares shall be made by one man in 2 min.

(*g*) Each cockpit window shall be replaceable by one man in 5 min. on all sliding glass and 20 min. on stationary glass.

Part 2

By J. L. Atwood

THIS paper is supplementary to the foregoing paper by J. H. Kindelberger. It presents a more specific treatment of the performance and structure of modern transport airplanes and a forecast of the next probable development in planes of this type.

Features of design discussed include the powerplant, together with the subjects of supercharging and the propeller; factors contributing to the aerodynamic refinement of the actual airplane; high-altitude flying; and structure, which is commented upon in considerable detail.

In conclusion it is stated that aircraft design is going ahead as rapidly as possible in this country, and the background of engineering knowledge and experience that has been gained in recent years will make it possible for the United States to hold the leading place in air transportation.

There is every reason to believe that the airplane eventually will be the chief means of transportation over any considerable distance, and the present trend and recent achievements are most encouraging.

THIS paper is a supplement to Mr. Kindelberger's more comprehensive paper. I shall limit it to a more specific, although rather superficial, treatment of the performance and structure of modern transport planes and will present also a forecast of the next probable development in planes of this type.

The last ten years have seen a remarkable increase in airplane speeds in all classes; in some cases the maximum speeds of a decade ago have been actually doubled. This is truly remarkable in itself when it is considered that to double the speed of an airplane requires that the power be multiplied by eight, or that the drag be divided by eight, or that an equivalent combination of both be effected. In many cases, particularly in racing planes, power has been added as fast as engine designers could produce it, comparing the 1924 Curtiss racers having D-12 engines with the latest Italian seaplanes of 3000 hp. It is actually a more important achievement, however, that modern transport planes, in which economy is always important, should be capable of an operating speed of over 200 m.p.h.

Until the development of the Boeing transport for United Air there was very little improvement in basic design from the time of Fokker's first tri-motor, but since that time designers awake to the possibilities and spurred by the competition aroused by a potential market have made great strides, improving transports to a point approaching the logical culmination of aerodynamic refinement coupled with a corresponding approach to mechanical and structural perfection.

Here it might be well to point out that practically no principles or devices have been employed in the development of these machines that were not well known theoretically for many years and, in most cases, practically as well as experimentally proved. The advance lies in the degree of coordination and perfection rather than in abstract scientific achievement, and for this reason this paper, although supposed to be an engineering treatise, can hardly do more than enumerate and discuss the features connected with recent developments which in general are well known to the engineering fraternity.

In discussing features of design, the powerplant deserves first place. This unit can be well defined and isolated, being based on the engine-manufacturer's product, with propellers and accessories of specialized manufacture, and with fuel and oil tanks, controls, cowling, structure and installation the responsibility of the airplane builder.

The practical application of the supercharger is, of course, the engine manufacturer's greatest contribution to improved airplane performance, providing increased specific power-output and making possible power at altitude up to the mechanical and structural limitations of the engine. The far-reaching possibilities of supercharging should not be underestimated, but this will be discussed more fully later on.

Engines have been refined and improved, but no basic changes have been made in many years. To the writer's knowledge no major changes are in prospect, other than the imminent probability of using fuel injection instead of carburetors and a possibility of the increasing use of Diesel engines.

The other important feature of the powerplant that should receive especial mention is the controllable, and the more recently perfected automatic propeller. The advantages of this unit are obvious, but the important effects and possibilities of this development on airplane design are a bit obscure, or at least have not been fully realized in some recent designs. Take-off, rate of climb and ceiling are not greatly affected by aerodynamic cleanness, and these factors are of great importance in a transport plane. The take-off should not necessarily be very short, but there will always be a practical maximum of distance allowable in the interests of safety.

The ceiling is also important, particularly in the event of the failure of one engine. A failure of a mechanical part is and always will be possible; but, with a modern independent engine installation, the chance of two engine failures on one flight is indeed remote. It is important then that a transport should be able to maintain a considerable altitude with one

engine stopped. In its specification for new transports, T.W.A. desired a ceiling of 8000 ft. with one engine stopped in order to clear certain high points on the route. The controllable propeller, of course, aids greatly in this, but the main point is that a transport should have enough power properly divided into units with controllable propellers to meet the above or any other desired performance, but only enough and no more.

The most uneconomical way to obtain increased speed is to add horsepower, and it should be emphasized here that the new Douglas and other high-speed transports carry almost exactly the same weight per horsepower as the obsolete planes of ten years ago. The controllable propeller is responsible for this to a considerable degree; for, with the high wing-loadings now in use, the take-off would be very sluggish with fixed propellers. Another effect has been to bring the bi-motored airplane into its own in that when one engine unit with a controllable propeller has the right amount of power to maintain the airplane at an altitude of approximately 10,000 ft., the operation on two engines is about right for take-off and economical cruising.

The automatic propeller, with a centrifugal governor which will maintain a constant number of revolutions per minute for any air speed or throttle setting, will certainly come into almost universal use within a short time and will permit even greater specific loadings. Take-off distance is reduced roughly 15 per cent; or, conversely, greater wing and power loadings may be employed for a desired take-off characteristic. Other features of the powerplant installation, such as cowling, exhaust manifolding, fuel and oil systems and engine controls, are simply problems in detail design, although quite difficult in many cases. This work is becoming uniformly good in nearly every case, as no powerplant is better than the installation work involved.

Factors contributing to the aerodynamic refinement of the actual airplane include higher wing-loadings, the use of wing flaps, elimination of external bracing, the retractable landing gear and the improvement in shape and arrangement of the fuselage, nacelles and tail. The trend toward higher wing-loadings has been quite pronounced for several years and the limit does not seem to be reached as yet. Reduction in wing area improves high speed directly by reducing the wing drag, and indirectly by reducing the size of the airplane. Reduction in wing area must, of course, be compensated for in landing for the improvement of the maximum lift-coefficient. This field has hardly been touched in practical airplanes in this country, although considerable experimental work has been done and the limit of the maximum lift-coefficient has not been nearly approached. The recent introduction of split wing-flaps has been the first real effort to improve the natural characteristics of an airfoil for landing purposes. This device increases the full-scale lift from about 1.4 to approximately 2, reducing the landing speed to around 16 per cent or permitting about 40 per cent higher wing-loading for the same landing speed.

The wing slots developed by Handley Page have not as yet found favor in this country, principally because to use the slots to full advantage the landing angle must be several degrees more than is practicable on a conventional airplane. However, this and other boundary-layer control-devices offer possibilities of increasing the maximum lift considerably more in the next few years. The disadvantages connected with higher wing-loadings are longer take-off distances required and inferior performances at altitude. The present tendency is to use high wing-loadings, but to maintain a good wing span with a corresponding reduction in chord; but this has its limitations also. At the present stage of development a wing loading of 24 lb. per sq. ft., or slightly more, seems to be the practical limitation for successful operation on landplanes.

Cantilever wing-construction is becoming almost universally used, and the biplane, with its inherent interference and span limitations for a given wing area, is practically obsolete. The reduction of parasite and interference drag has been really remarkable, and the modern transports seem to be approaching a practical minimum in this respect.

The retractable landing gear has at last become almost universally accepted and, although its merits are open to question by some, there is no doubt that without this feature no airplane can approach its ultimate in speed and economy. The mechanical difficulties have been very readily overcome and the argument of increased weight is not important, even from the economy standpoint and, when present competing schedules call for the maximum in cruising speed, the intrinsic value of the retractable gear is hard to estimate.

The aerodynamic refinement then has reached a point where only the necessary component parts of the airplane are exposed to the airflow, and these have been improved in shape and relative location by careful wind-tunnel testing until further improvement along this line will be extremely difficult.

The future possibilities of increased speed then must lie in some other direction. Unless the premium on speed becomes considerably greater it will be uneconomical to add more horsepower directly, since to improve the cruising speed from 200 to 250 m.p.h. would require that the horsepower be doubled, with a corresponding increase in fuel consumption The merits of altitude flying have been known for many years and considerable scientific work and speculation have been done regarding the so-called stratosphere-airplane. If parasite and friction drag only are considered it is possible to increase the speed, the power remaining constant; roughly, one per cent for each additional 1000 ft. of altitude near sea level, increasing slightly until, at 50,000 ft., the increase is 87 per cent. The induced drag, which is a negligible factor in high speed near sea level, becomes more and more important at altitude and there is an absolute ceiling for any airplane even though full power is maintained; but at any rate there is a great advantage in performance in altitude flying.

The possibilities of high-altitude flying have been touched only in a limited way, largely because of the fact that passengers cannot withstand the reduced atmospheric pressures and lack of oxygen for long periods at altitudes much greater than 12,000 to 14,000 ft. Our present-day transports are supercharged to maximum power at about 7000 ft. and obtain their most efficient cruising speeds at about 14,000 ft., where speeds of 200 m.p.h. or better are being obtained while using 75 per cent of the rated engine-power. This represents a gain of approximately 25 m.p.h. over sea-level performance with the same power output, and is an indication of the possibilities when cruising at much higher altitudes.

There are many difficulties to be overcome before a successful stratosphere-plane can be put into regular operation. One of the chief difficulties is the construction of an airtight pressure compartment for the passengers and a supercharger to keep it supplied with fresh air at the required pressure. This in itself is not an impossible problem by any means, but the incorporation of this mechanism and construction in an airplane where any possibility of failure would be extremely

dangerous or perhaps fatal to the passengers is a problem which all engineers view with considerable apprehension and such a development must be based on extremely sound research and actual practice. The structure itself would be comparatively simple, as an airtight fuselage to hold an air pressure of 6 to 8 lb. per sq. in. is quite feasible, and the sealing of entrances and other openings is by no means difficult; but the necessity for a continuously operating and foolproof supercharger presents a much more difficult problem. Its operation must be entirely automatic, as the uncertainties of any personal element must be eliminated. Rapid changes in pressure of any considerable magnitude have a severe physiological reaction and may even prove fatal if extreme in nature. When perfected, there probably will be at least two independent engine-operated units, each capable of maintaining a cabin pressure independently. Supplying air for the engines is also a difficult problem, and requires a considerable percentage of the engine's power at high altitudes.

The problem of propeller design for altitude flying involves the use of a propeller of considerably greater diameter, and the necessity for keeping the tip speeds to approximately 1000 ft. per sec. will necessitate a lower number of revolutions per minute. The automatic control mentioned before, however, will make possible a much wider range of variations from take-off to operation at altitude, with less loss in efficiency than has been possible previously.

These difficulties, however, will be overcome eventually and the great advantages of high-altitude flying will be made use of. Cruising speeds of 300 m.p.h. or more are confidently predicted within the next ten years without greatly altering the aerodynamic design or appreciably increasing the power loading. Research work on this type of airplane is being done by various manufacturers, government agencies and universities, and the engineering difficulties will, undoubtedly, be overcome; but here it might be well to point out the limitations of such an airplane from the economic and operation standpoint.

It is now possible to make a transcontinental flight in one night without loss of a business day, and whether or not there will be a sufficient premium on speed to warrant the use of the stratosphere plane is doubtful in the minds of some. Another consideration is the fact that, to attain its maximum efficiency in station-to-station time, each flight should be comparatively long. In fact, it is doubtful if more than one stop should be made in a transcontinental flight when cruising at 30,000 or 40,000 ft. The principal advantage of this type of airplane probably will lie in extended flights, such as across the ocean, and for special transcontinental traffic. For regular runs of 500 or 600 miles, it probably will be a long time before the present transport planes are obsolete.

Structure

The structure of high-speed transports, in common with large high-speed military-planes, is aluminum-alloy metal-shell type of construction. There are several reasons for the present trend to monocoque construction, one of the principal ones being that the torsional rigidity necessary in cantilever wings and tail surfaces is obtained most readily by means of a sheet-metal-covered structure. At high speed, torsional rigidity is essential to safety; otherwise, flutter may result, and the most rigid wing for its weight is the metal-covered type. Another reason for metal construction is the fact that maintenance is much simplified. The tendency is to use Alclad, or duralumin with thin aluminum coating, and to eliminate external finishes entirely, using only a light coat of oil varnish on the interior surfaces. Corrosion is almost negligible, at least when not operating around salt water, and the maintenance required for this type of construction amounts to almost nothing.

Still another advantage of the shell type of construction for the fuselage is the fact that a maximum of interior space is available for a given size and the desired external aerodynamic proportions. The interior can be made free from cross bracing and with the maximum of head-room without increasing the external dimensions, as would be necessary in fairing around the rectangular cross-section of a truss-type fuselage. As a final advantage, the shell type of structure is much safer in a crash because there are no struts to buckle suddenly and pierce the cabin, and the shell itself is quite resilient and can absorb a large amount of energy by crushing and buckling without losing all its structural strength.

In actual construction the shell type of structure has proved to be quite economical and the modern tendency is to follow ship-building practice, using the mold loft to develop lines and templets. Also, some successful efforts have been made to use the hydraulic press and the drop hammer for forming many complicated sheet-metal parts. Where the volume of production warrants the use of these machines, the results are most gratifying. However, at the present stage many shapes are still made by hand on flanging machines and forming blocks, and the shell plating is usually cut to templets and put on in long strips without any forming whatever.

Perhaps the most expensive feature of sheet-metal construction is the riveting, particularly on large assemblies where, usually, some of the rivets are rather inaccessible. Wherever possible, units are riveted up in small assemblies and machines are now in use which will punch a hole, insert and head a rivet; much time being saved in this way. Where sheets must be riveted to large units, holes are usually punched in stiffening members before assembly and a drill run through on assembly, the rivet being inserted by hand and headed with a pneumatic riveting-tool. There has been considerable effort to develop successful spot-welding for aluminum alloy; but, thus far, the results have been only fair. The spot-welding machine is very heavy and entirely unportable because of the extremely large amperage required to make successful spots. Some spot-welding is being done, however, on nonstructural parts, but as yet almost no structural assemblies are being assembled by spot-welding.

There are almost infinite possibilities of improvement in the detail design and construction of sheet-metal structures, particularly in regard to ease of assembly and cost. There is as yet no "standardized" construction for this type of structure, although it is becoming almost universal practice on fuselages to provide light ring-type formers to hold the section in shape and longitudinal stringers, spaced 6 to 8 in., slotted through these ring formers. There are a number of variations of this construction and some manufacturers have eliminated the longitudinal stringers entirely, depending on flat sheet only for longitudinal strength; usually, however, at the expense of considerable weight. Usually, the longitudinal stresses introduced by bending are carried largely in the longitudinal stiffeners and the shearing stresses in the flat sheet covering, which is broken up into comparatively small panels.

The problem of shear stresses in these structures has never been subjected to a very precise mathematical analysis and, in nearly every case, the design has been based on results of tests, since buckling will invariably occur in thin curved sheets of this type at relatively low stresses. The action of

these panels is most probably a combination of pure shear and tension and theories have been evolved for their design, assuming pure tension and neglecting the compression components in the panel. The true condition is probably shear at small stresses almost entirely, gradually changing to almost pure diagonal tension at extremely high stresses, and it is usually a matter of designer's judgment as to where he wants to stop. The diagonal compression components invariably cause slight buckling at small stresses, which become more and more pronounced, and the wrinkles become so large as to throw the structure completely out of line and become permanent deformations long before the sheet will actually rupture. For this reason it is good practice to design the structure so that the wrinkles are not perceptible when standing at static load or flying at a load factor of about one-and-a-half times gravity. This will automatically govern the wrinkling at high load-factors, but usually the buckling does not become permanent at an applied load-factor of approximately two-thirds of the ultimate strength. This is a satisfactory, if not entirely scientific, design criterion for shear panels and normally corresponds to a shear stress at static load of approximately 1500 to 2000 lb. per sq. in. for normal curved fuselage panels.

A design of the compression members is a bit more accurate in that panels of the shell with both skin and stiffeners are tested in compression to the point of buckling and the allowable stresses obtained from these tests are used in design of the fuselage, using calculated stresses from the ordinary flexure formula. This, however, is not entirely precise because of unusually large shear deformations in proportion to the cross-section dimensions, but usually results in a reasonably close design. Generally, the completed structure is stronger than tests of component parts indicate; but it is not reliable to assume that this is the case unless checked by static test of the complete unit.

The entire structural design is essentially a study in compression stresses, since tension is usually not critical and, at points where it is definite, ultimate strengths are known. With the formed shapes used in aircraft construction and the varying gages, it is usually difficult to determine the compression strength of sections without tests. Considerable experimental work has been done on this problem and this, coupled with experience, usually gives the designer a good idea of the approximate stresses a section will sustain. But, ordinarily, tests of typical sections are made under conditions simulating as nearly as possible the actual airplane.

The most efficient form for compression members is, of course, a tube; but tubes can rarely be attached properly to the formed sheet metal and hence various shapes are used which are either extruded, broken or drawn through a die. Closed sections are usually most efficient but are uneconomical in many cases, and a large number of bulb angles, channels, and other more complicated shapes, are used. Lightening holes are stamped in webs of channels and other points where practicable, and they often have the effect of increasing the stiffness, particularly where a large unsupported area of flat sheet is necessary. However, the total amount of weight that can be saved by means of lightening holes is usually small and, therefore, the practice is not carried to extremes, as is done in the case of dirigible construction where literally miles of flanged girders are used.

Cantilever wing-construction presents one of the most difficult problems that structural designers have to face, and it is safe to say that practically no two designs are similar in this respect. There is a diversity of opinion as to the most efficient type of construction, but it has been the writer's experience, covering several different types of cantilever metal-wings, that there is very little to choose from a weight standpoint between the types now in vogue. There is, however, a great deal of difference from the standpoint of service and constructional cost.

It is certain that thin metal covering cannot be applied satisfactorily as though it were a fabric cover without supports and stiffeners, because small shear stresses will produce large wrinkles that cause eventual cracks and failures and, in addition, have a very unsatisfactory psychological effect from the standpoint of passengers who observe these wrinkles. Two types are apparently satisfactory; one consists of beams and ribs with a corrugated or beaded covering having corrugations running fore-and-aft and at least partially supported by internal stiffeners attached to the corrugations. In this case the beams carry all the bending loads and the corrugated cover resists shear loads imposed by drag forces and torsion. The other type, which is more popular at present, consists of one or more continuous webs with ribs and stiffeners notched through the ribs that run essentially parallel to the webs and riveted to the flat-sheet outer-covering, acting as flanges in a beam, the shear being transferred by the webs and metal cover to the stringers which act in compression and tension. This type of wing is most efficient when no large cut-outs or holes are necessary in the wing and the complete shell is effective in compression and tension. The external appearance is very satisfactory because the relatively close spacing of stringers prevents the formation of large wrinkles and, in addition, there is some economy of material in utilizing the skin for tension stresses and to a lesser degree for compressive strength.

Strength of Thin Metal Sheet

Flat sheet in compression begins to buckle at relatively small stresses, but in its buckled state has not actually failed in any true sense of the word; this is merely a condition of elastic instability and continues to resist compressive loads even though the buckles are quite pronounced. The portion of the skin adjacent to the lines of rivets on the stringers is considerably more effective, and so a certain percentage of the shell cover on the compression side is usually considered in resisting compression. This percentage is rather arbitrary, being based on tests, although some excellent theoretical work has been done on determining the strength of thin sheet in compression.

The principal problems in wing design present themselves at points where it is necessary to mount heavy units, such as engine nacelles, the attachment of landing gears, and points where it is necessary to insert fuel tanks or other internal items. There is a great need for improvement in wing structures, principally from the manufacturing standpoint, to give greater accessibility for construction and to enable construction of the wing in sub-assemblies as much as possible.

Other structures in aircraft usually present problems more in the nature of detail design and arrangement, and the manufacturing cost of these items depends on the design of each individual part. Auxiliary structures can be made in almost any type of construction that can be properly attached to the main units. There is no standard method of construction, although units such as brackets, supports and other internal auxiliary structures, are usually made of welded-steel tubes and gusset plates or of sheet metal similar to the bulkhead and rib construction used in major assemblies.

The design of landing gears has shown a great deal of ingenuity on the part of designers, and no two are ever alike as far as arrangement goes. The construction, however, is almost invariably of steel tubes, forgings and machined parts, usually assembled by welding and heat-treated afterward. One of the principal reasons for the popularity of the low-wing monoplane has been the fact that the landing gear is more readily retractible using this arrangement, but even then considerable difficulties are encountered. Landing gears are retracted by either mechanical or hydraulic means, each system having its advocates at present. Mechanical retraction is usually accomplished by means of a worm gear and pinion, cables, or sliding tracks, while the hydraulic gear is ordinarily operated by means of folding linkages actuated by a hydraulic cylinder.

The hydraulic mechanism is most efficient in that it has comparatively small friction losses and is usually easier to install because of the ease with which hydraulic lines can be carried to any part of the airplane. Also, it is not normally affected by ice or dust. There are many difficulties with the hydraulic system, however, principally in the construction of valves, which usually must provide four outlets and be made reversible, easy operating and leak-proof. Other parts of the system such as pumps, fittings and flexible connections have been used with complete satisfaction. Satisfactory valves have been recently developed which promise to make the hydraulic system by far the most satisfactory type for both operation of the retractable landing gear and of the wing flap. On larger airplanes an electric motor-driven hydraulic-pump is desirable, with an emergency hand-pump, for the reason that the work required in retracting a large gear is too much to expect the pilot to perform.

One of the most difficult and important parts of the structural development is the design of fittings and joints where the major component parts are attached together. This work requires the utmost ingenuity and a sound knowledge of the loads imposed on the structure, and really good structural-fitting designers are comparatively rare. A combination of familiarity with shop practice, mechanical engineering, structural engineering and several years of experience, are usually necessary to produce satisfactory fittings, as a structure is often developed around the major attaching points. Aircraft fittings are usually made of either aluminum-alloy bar, steel bar, forgings where the quantity indicates, or welded-steel-plate assemblies. Many times these fittings, as in retractable landing gears, must take severe pounding loads and still be capable of precise mechanical operation. Usually, these joints consist of machined or forged bars welded or shrunk into steel tubes, with heavy lubricated bushings with reamed holes and alloy-steel bolts with very small tolerances.

Design of other joints, such as in the control system, are usually problems more of a mechanical nature but, of course, these mountings must be designed for ample rigidity, which is not always easy when mounting in a light aluminum-alloy-sheet structure. Sealed cartridge-type ball-bearings are used throughout for all pulleys and control-system joints.

The installation of equipment, particularly the powerplant, is always a large problem in exacting detail design. Engine controls, for instance, must be extremely rigid and severe load and deflection tests are applied to these systems. These and other installations are designed with a precision rarely found in any other unit the size of a modern transport plane. All these requirements, together with the necessity for a minimum of weight, make it quite apparent why it is necessary to spend 100,000 or more engineering hours in developing a modern transport airplane.

The future of air transportation is indeed bright, and only the recent developments in facilities and equipment have made possible for the first time a really efficient and safe system. One of the most important features, although not within the scope of this discussion, is the radio with its recent refinements including radio beams and direction-finding equipment which have made the navigation and dispatching of aircraft simple, safe and sure.

The next important step in transport design will be, in the opinion of the writer, a bi-motored monoplane of from 30,000 to 40,000 lb. gross weight and powered with two engines of from 1000 to 1500 hp. each. The cabin will be sealed and supercharged, and the engines designed with superchargers to hold maximum power up to 25,000 ft. The normal cruising altitude should be around 35,000 to 40,000 ft. and an operating speed of 275 to 300 m.p.h. will be achieved, making possible a transcontinental flight in 9 to 10 hr. This development is possible at present but it is predicted that six to eight years will pass before this plane becomes a reality because, as mentioned before, the economic pressure may not be sufficient to force its immediate development. In addition, the recently acquired modern equipment will not be discarded for some years.

Aircraft design is going ahead as rapidly as possible in this country, and the background of engineering knowledge and experience that has been gained in recent years will make it possible for the United States to hold the leading place in air transportation. There is every reason to believe that the airplane eventually will be the chief means of transportation over any considerable distance, and the present trend and recent achievements are most encouraging.

A Rational Basis for Comparing Diesel-Engine Performances

(Concluded from page 214)

In this paper another use was made of the analysis merely to explore the state of progress in quite separate fields, as a matter of interest.

For reference, the following is a summary of the information required to calculate the characteristic curve:

(1) Barometric reading and atmospheric temperature
(2) Lower heating value of the fuel
(3) Friction mean pressure, or equivalent data
(4) Fuel consumption at several brake mean pressures

The characteristic will apply to the speed in revolutions per minute at which the test was made, but may be considerably different at another speed.

It is the author's thought that Diesel engineering would be advanced if engineers agreed upon a common basis for stating their results, or at least quoted such data as would permit the result to be analyzed. The object in this paper has been to describe a method of analysis which is easily applied but which takes account of all principal factors. Incidentally, the method applies as well to gasoline spark-ignition engines as to oil engines. Moreover, interchange and publication of information is in itself a long step toward progress in engineering. In this respect the Diesel-engine industry seems to be distinctly in the rear as compared with other branches of machinery engineering, both mechanical and electrical.

"We in the aeronautical field consider the S.A.E. a highly valuable institution, particularly for the exchange of ideas and information which it makes possible."

—C. L. Egtvedt, *President*
Boeing Aircraft Company

MR. EGTVEDT, head of one of the world's foremost producers of commercial and military aircraft, started his career as a draftsman for the Boeing company. In going to the presidency, he held such positions as assistant chief engineer, chief engineer, secretary, vice-president and general manager. He has been associated with the Society of Automotive Engineers since 1919.

THIS PAGE IS PRINTED FOR THE INSPIRATION OF OUR PRESENT MEMBERS—FOR PRESENTATION TO PROSPECTIVE MEMBERS

News of the Society

(Continued from page 14)

Butane as Fuel Is Meeting Topic

● **Oregon**

"Unless some very definite improvements are made in gasoline carburetion to overcome its wastefulness, gasoline cannot last as a motor fuel." This was the position taken by G. L. Holzapfel, president of the Holzapfel Instrument Co., Los Angeles, at the May 8 meeting of the Oregon Section. Mr. Holzapfel in presenting the comparative advantages of the butane carburetor, said that he does not feel that butane is the last word in motor fuels but that it is an important link in the evolution of the motor fuel of the future.

He pointed out that during the past 18 months butane has been used commercially in about 2000 vehicles in California. This fuel is being sold commercially in some filling stations in Southern California, but so far its use has been confined largely to foreign and commercial equipment and the refueling is done at one or two scheduled points.

A lively discussion followed presentation of Mr. Holzapfel's paper, continuing for an hour after the official adjournment of the meeting. Among those participating were: W. H. Paul, instructor in automotive engineering, Oregon State College; S. C. Schwarz, chemist, Refining Industries, Inc.; H. D. Hertz, a student at Oregon State College, and L. O. Johnson.

Harley W. Drake, retiring chairman of the Section, was presented with a bronze S.A.E. desk emblem on behalf of the Section members by J. Verne Savage who succeeds Mr. Drake as chairman.

The student activity efforts of the Section were furthered by the donation of a Stromberg marine carburetor for the rowing coach's boat of the Oregon State College. The gift was made through A. J. Lilygren of the Bendix Corp. H. W. Roberts, of the Roberts Motor Co., donated a 58 hp. engine for the boat.

The Oregon Section has maintained high interest in the work of the Mechanical Engineering Department of the Oregon State College. On Saturday, May 25, several members of the Section spent the day at the College touring the engineering laboratories and shops, witnessing a crew race between the Oregon and Washington State Universities and playing golf at the Corvallis Country Club. In the evening they participated in a dinner of the Founder Societies interested in Oregon State's engineering work. Welcome was provided by President Peavy of the College.

The May meeting was the last meeting of the season for the Oregon Section and while attendance was rather limited it was representative of all the branches of the automotive industry located in the vicinity.

Chemical Warfare Ideals Explained

● **Washington**

At the Washington Section meeting held May 6 at the University Club, 9 members and guests attended the dinner and 45 were present at the technical session. The speaker was Lieut. Comm. T. L. Schumacher (CC), U.S.N., who presented a paper on "Chemical Warfare."

After reviewing the history of the subject and clearing some popular misconceptions of the effects of chemicals on human beings, the speaker cited the chemical agents which are satisfactory for war usage and classified them according to their physiological effects. Among these are the "lacrimators," commonly called tear-gas; the "sternutators," or irritant smoke; the lung irritants; the incendiary types which burn furiously while throwing off molten sparks; and the "vessicant" type, of which one example is the so-called mustard gas.

Methods of usage of these agents and means of protection from their effects were described. The speaker said that increased effectiveness of chemical warfare, if any, probably will be due to improvement in the technique of using the existing chemicals, rather than the development of new chemical agents. Further, that perhaps the most important and far-reaching development in chemical attack will be the development of airplanes and the technique of delivering chemical attacks from them, such as the spraying of given areas with chemicals, probably of the mustard type.

Holzapfel Gives Second Reading

● **Northwest**

The Northwest Section held its last meeting of the current season at the New Washington Hotel in Seattle with an attendance of 50 members and guests. The paper of the evening was G. L. Holzapfel's "Future of Butane as a Motor Fuel," presented May 8, at an Oregon Section Meeting. Mr. Holzapfel illustrated his paper with many lantern slides depicting butane carburetor construction, butane tanks and butane-equipped tractors and trucks. As at the Oregon meeting, a spirited discussion followed the paper.

James H. Frink, vice-chairman of the Section and assistant to the manager of the Washington Iron Works, Seattle, presided at the meeting in the absence of Chairman J. G. Holmstrom.

Plant Inspection At Belle City Iron

● **Milwaukee**

The program for the May 1 meeting of the Milwaukee Section began in the afternoon with a plant inspection at the Belle City Malleable Iron Co., the members and guests witnessing the production of malleable-iron, electric-steel and cast-iron automobile-parts.

The dinner in the banquet room of the Hotel Racine was attended by 119, and was given with the compliments of the Belle City Malleable Iron Co. and the Young Radiator Co. The speakers at the technical session were: D. Porter Spencer, metallurgist, Belle City Malleable Iron Co., subject, "Development of Electric Furnace Cast Iron," and Russell J. Anderson, assistant superintendent of this company, subject, "Machineability, Engineering Properties and Applications of Electric Furnace Cast Iron."

Section Discusses Various Topics

● **No. California**

C. A. Klaus, assistant chief engineer, Thermoid Rubber Co., Trenton, N. J., gave an informal talk on new developments in brake lining at the March 19 meeting of the No. California Section. In the course of his remarks he said that the present trend in brake lining application seems to be toward discarding molded lining and returning to the woven type. After Mr. Klaus' talk S. B. Shaw, automotive engineer, Pacific Gas & Electric Co., took charge of the meeting and introduced the remaining speakers. W. E. Tice presented an unusual point of view on the trend in tractors and trailers emphasizing the unlimited life of trailers and semi-trailers in long-haul use.

Other talks were given by Messrs. Neely, Klemgard, Efferman, Rice, Stalnaker, Becker, McGregor, Echlin and Wildhagen. The subjects ranged from lubricants and fuels to piston ring and ignition problems and was thoroughly enjoyed by the 98 members and guests of the Section present.

The regular April meeting of the No. California Section followed on the 9th in Oakland, Calif., President Stout's visit to the Section on the 4th at a meeting held in San Francisco. Although it was the second meeting of the month for the Section, 135 members and guests turned out to hear Elliott G. Reid, professor of aerodynamics, at Stanford University.

Mr. Reid emphasized effect of wind upon scheduled airline operations. After describing the intricate meteorological service which the Government and airlines must maintain for the study of air currents and other data, Professor Reid gave a brief discussion of the hazards of ice formation on wings and the means taken to combat it. J. F. Long, chairman-elect of the Section, presided at the meeting.

Bramberry Turns To Diesel Problems

● **Indiana**

The meeting of the Indiana Section held April 11 at the Athenaeum, Indianapolis, proved the drawing power of Diesel meetings by an attendance of 192 at the technical session, which featured a profusely illustrated and intensely interesting paper on "Piston-Ring Problems of Diesel Engines," by Harry M. Bramberry of the Perfect Circle Co., together with a round-table discussion of the paper and the general topic by Diesel experts. Among these were Clessie L. Cummins, president of the Cummins Engine Co.; Clyde Schuler, of the Hercules Motors Corp.; Ralph R. Teetor of the Perfect Circle Co.; and John T. Whitaker of the Ross Gear and Tool Co. The dinner attendance was 71.

Mr. Bramberry's paper followed closely a large lantern-slide collection which showed microscopic sections of cylinder and liner and ring metals and various alloys used in these parts, and the relation in hardness between cylinder and liner metals and piston-ring alloys for best results. The importance of extremely smooth finish for cylinder and liner walls for best Diesel operation was brought

out, as well as the better results obtained along these lines with the more modern alloys. The better rings are invariably somewhat softer than the cylinder walls, and the size of the rings has been quite accurately set at proper dimensions with various cylinders by Perfect Circle Co. research work.

The extreme difficulty of maintaining rings where cylinders and liners are not adequately water cooled in the extreme-pressure loads of some Diesels was shown; also, the advantage of employing the newer alloys for cylinder or liners, even where proper and adequate cooling has been provided, because of longer wear.

Mr. Cummins questioned the need of "trick alloys and high-price metals where proper cooling is provided and where pressure loads have been reduced." With his special design certain types of aluminum pistons had a tendency to run too cool, but he pointed out that to attempt success without thorough water jacketing, as had been tried at times in the past, was out of the question. He agreed that proper temperatures must be maintained if the oil film is to be continued and that of course no ring or piston will stand up long if the temperatures are so high that the film is endangered. "We must also insure that the fuel is completely and cleanly burned if we mean to maintain the oil film," he said.

The need of adequate air filters of a size large enough to keep the air fairly clean was brought out by A. W. Herrington, who told of two identical engines equipped with air strainers of the same make, where one failed completely and the other endured steady running in a desert without damage under extreme conditions. One had been equipped by the engineering department; on the other, a purchasing agent saved a little money by buying a smaller filter, to the utter ruin of the engine after a short time.

Clyde Schuler and John T. Whitaker also asked questions that brought explanatory answers from Mr. Bramberry.

Transport Problems On Canadian Agenda

● **Canadian**

Two papers on transportation problems were given at the April 17 meeting of the Canadian Section held at the Royal York Hotel, Toronto. R. E. Fielder, manager, coach division, Yellow Cab Manufacturing Co. of Canada, Ltd., presented a comprehensive selection of slides on "The City Coach" with a running commentary on each type shown. E. J. Cosford, president, Associated Equipment Co. of Canada, Ltd., described some applications of Diesel engines in the transport field. The digests of both these papers will be found on p. 19 of this issue of the S.A.E. JOURNAL.

In the course of the discussion which followed the papers, H. R. Holder, superintendent, auto bus department, Montreal Tramways Co., stated that the experience of his organization with its initial and tentative Diesel installation was a saving of $1,500 in fuel cost alone for every 50,000 bus-miles of operation. Servicing cost, he said, was approximately on a parity with that of gasoline-engine driven units of otherwise duplicated design, while the oil economy of the Diesel unit was definitely better than that of the gasoline engines. This has led his company, he said, to supplant gasoline engines with Diesels in 15 cases. He indicated that this was only the beginning of the transition, giving it as his opinion that a much larger number of units would be converted during the ensuing year.

Mechanical Features of 1935 Cars Brought Out in Paper & Questions

● **Metropolitan**

Harold F. Blanchard, technical editor, MoToR, presented "A Discussion of 1935 Cars" at the May 13 meeting of the Metropolitan Section. Mr. Blanchard's paper was preliminary to the annual "proving ground" tests of the Metropolitan Section which were held two days later at the Glenn Curtiss Airport, Jackson Heights, L. I. In his paper Mr. Blanchard gave a point by point description of the most important innovations in the 1935 automobiles, beginning with the centrifugal supercharger on the Auburn and ending with the hydraulically actuated duo-servo brake shoes on the Studebaker models. With his paper he presented a table of new car specifications showing for each make and model the number of cylinders and valve arrangement, bore and stroke, piston displacement, taxable horsepower, maximum brake horsepower with accompanying engine revolutions, standard compression ratio, cylinder head material, gear ratio, tire size and diameter, shipping weights and wheel bases.

Representatives of several automobile manufacturers were at the meeting to answer questions about the new cars. These representatives included Henry M. Crane and W. J. Davidson of General Motors, M. E. Kane and V. W. Helard, Ford Motor Co., E. M. Rice and C. M. Bouts, Chrysler Corp., R. J. Marr and C. F. Norfolk of the Hudson Motor Car Co., C. E. Anderson of the Packard Motor Car Co. and S. I. McGrath of the Auburn Automobile Co.

As in a similar meeting last year, much of the discussion hinged around suspension systems with the independently-sprung types warmly defended by General Motors advocates and more or less conventional leaf-spring types having comparatively soft front springs favored by Chrysler and some other advocates. It was even intimated by a representative of one maker of both forms of suspension that the independent type would now be out entirely in cars of this make, partly because of high cost, except for a large investment in tools for producing that type. On the other hand, there were words of commendation spoken for the new Studebaker and Packard independent suspensions as well as for the forms used by General Motors.

Among the points of design criticized by various discussers were: poor visibility in some body designs, presence of carbon monoxide in the exhaust, failure to provide better streamline forms, lack of an oil filter on some cars, difficulties involved in jacking and tire changing, inaccessibility of batteries and failure to provide more spacious bodies or to make better use of space within the chassis length for carrying purposes.

Items which were commended in current models included better riding qualities with both conventional and independent suspensions, the use of over-gears at high speed, weight decreases effected in certain cases, use of the "turret-top," application of superchargers to boost power with very little weight increase, improved steering, freedom from vapor lock troubles, elimination of free-wheeling on most cars and the use of clutches with lower throw-out pressure.

Herbert Baxley acted as chairman of the meeting, which is the last technical session of the Section scheduled for the current season.

Transportation Show Is Immense Success

● **Baltimore**

An educational transportation exposition, the largest of its kind ever held in Baltimore, was held at the Holabird Quartermaster Depot May 2, under the sponsorship of the Baltimore Section. The exhibits included modern trucks and transportation equipment, and many vehicles of

● **Baltimore**

This vehicle is believed to be the first all-wheel drive truck built in the United States. It was designed and assembled at the Holabird Quartermaster Depot in 1925 from units built by commercial manufacturers to government specifications. One of a number of historic transport vehicles exhibited at the Baltimore Section's Transportation Show held May 2 at the Holabird Quartermaster Depot.

historical interest. The Q.M.C. shops were open for inspection.

Although heavy rains preceding the day of exhibit made the proving ground of the depot a sea of mud, the attendance for the day was 1125 persons. All the leading truck dealers in Baltimore cooperated in exhibiting modern equipment. Supper for the visitors was provided by an Army field kitchen.

Piston-Ring Problems Set by Robertson

● **Philadelphia**

The last scheduled meeting of Philadelphia Section, held on May 8, featured a paper on "Factors Governing Performance of Pistons and Piston Rings," by D. D. Robertson, chief engineer, Wilkening Manufacturing Co. J. P. Stewart of Socony-Vacuum Corp. was chairman. Attendance was about 30 for dinner and over 100 for the meeting.

Mr. Robertson discussed at length the problems entering into control of oil consumption, control of blow-by, and the life of the piston assembly under modern service conditions. Clearance of pistons in cylinders is found to have a great effect upon oil consumption. While the clearances necessary for manufacturing practice vary between 0.0015 and 0.0025 in., the increased oil consumption between the high and low figure may run as high as 25 to 30 per cent, thus accounting for variations between cars of the same make.

Side clearance of piston rings in grooves is most important and minimum clearances of 0.0015 for the top ring and 0.001 in. for the others is recommended to avoid sticking. Compression ring clearances should be held to the low limit to prevent blow-by.

One of principal causes of piston slap and high oil consumption with split skirt alloy pistons is the increased piston clearance from collapse of skirt. Piston expanders and band piston resizers are being used successfully to correct this condition.

Mr. Robertson pointed out that oil consumption and blow-by go hand in hand and that generally improved oil mileage is accompanied by increased blow-by. However, blow-by is considered to be an important factor in controlling oil and within certain limits is neither dangerous nor objectionable.

The author brought to bear a large variety of illustrations of test results which show the effectiveness of a new ring design produced by his company in which the ring is of the wide channel type featuring a special undercut groove. Another advance in this direction is the increased use, in oil control rings, of drilled holes instead of slots as a means of providing drainage.

The discussion of this interesting paper was easily one of the liveliest this season. Among those participating were: William K. Toboldt of *Automobile Trade Journal*, J. C. Geniesse, J. B. Franks, Jr., J. P. Stewart, B. B. Bachman, J. E. Fernley, Harry F. Huf, R. E. W Brewer, F. L. Creager, and P. M. Heldt.

O.S.U. Meeting Draws Crowd

"Copper Strands of Commerce" was the subject of Mr. Hoover, of the Ohio Bell Telephone Co., at the April meeting of the S.A.E. Student Branch at Ohio State University. Attendance at the meeting was 120. Plans by the Branch for the remainder of the year call for a visit to the Waco aircraft factory and to Wright Field at Dayton.

Buffalo Holds Record Meeting

● **Buffalo**

With two aircraft papers on the program and the additional attraction of being "Ladies' Night," the May 14 meeting of the Buffalo Section drew an attendance of 153 with 91 at the dinner which preceded the meeting. The speakers were: Ralph S. Damon, president, Curtiss Aeroplane & Motor Co. Inc., whose subject was "Manufacturing Transport Planes," and William Littlewood, chief engineer, American Airlines, who spoke on "Modern Transport Flying." E. F. Lowe, assistant general manager of the Society, who attended the meeting, described the plans for the Summer Meeting at White Sulphur Springs in June. All of the talks were informal in character with no prepared manuscript.

Among the new developments in manufacturing and design, mentioned by Mr. Damon, was the uniform equipment for blind flying now being developed by the Sperry Gyroscope Co., Inc. The aircraft industry is looking forward to the development of planes of 40 passenger capacity for ordinary service by 1936 or 1937, according to Mr. Damon. The variable pitch propeller now being widely used will probably be developed to the completely automatic stage by that time and air pressure in cabins will be maintained at the sea-level figure for the comfort of passengers.

Recent engine and carburetor advancements have been very marked, Mr. Damon said, and mentioned specifically the development of the automatic mixture control. He cautioned the audience, however, that some of these developments are proceeding so rapidly that they would be nearly obsolete before being put into general use. He mentioned the fuel injection engine as a coming possibility and believes that the manufacturer of transport airplanes will find new utility with engines of a thousand horsepower or more of relatively low specific weight. Fuels with an octane number in the neighborhood of 100 will be a contribution to the rapid advancement of the aircraft transport field. Airplane manufacturers are making every effort to keep up with the demands of operators, Mr. Damon pointed out.

Mr. Littlewood explained in some detail the operation of a modern air transport plane from the operator's point of view, showing particularly the extent to which operators go in checking planes to be assured of their safe and economical operation. He showed moving pictures of planes in service and the communications system for the dissemination of weather reports and other information for the safety of the flying public.

Laurence P. Saunders, retiring chairman of the Section, thanked his fellow officers, committee chairmen, and members of the Section for their loyal support and cooperation during his administration. The meeting was the largest held by the Buffalo Section.

Metals Analysis With Equipment Shown

● **Dayton**

"The Quantitative Spectro-Chemical Analysis of Materials" was the subject of the April 12 meeting of the Dayton Section. The speaker was Dr. E. G. Martin, and he presented an elaborate display of equipment in connection with his talk. Attendance at the meeting was 180.

Nutt Links Design And Operating Work

● **Dayton**

The concluding meeting of the 1934-1935 season was held by the Dayton Section at the Dayton Engineers Club May 9 and drew an audience of 80 members and guests. Arthur Nutt, vice-president in charge of engineering for the Wright Aeronautical Corp., Paterson, N. J., presented a paper entitled "A Discussion of Military and Commercial Aircraft-Engine Design and Operating Problems".

In this presentation, the speaker discussed the life and maintenance of commercial airplane engines as affected by oil and fuel. A comparison of weight and performance characteristics of American and European air-cooled and liquid-cooled engines was given with the assistance of curves and charts; also, the possibilities of power gain by further supercharging when higher-octane-number fuels are commercially available. A lively discussion on these points followed, which also brought to the fore the subject of fuel-injection engines.

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Expert Handling for Summer Meeting Golf

Herbert L. Sharlock

Herbert L. Sharlock, who will be chairman of the S.A.E. golf committee at the 30th Anniversary Summer Meeting at White Sulphur Springs, is in charge of arrangements for the Western Open Golf Championship in his capacity of president of the South Bend Country Club where this important national golf fixture will be held this year.

The Western Open will finish just in time to permit Mr. Sharlock to reach White Sulphur to begin the no-less-important-to-contestants S.A.E. tournament. The S.A.E. championship will be 36 holes of medal play and will be run off on Monday, Tuesday, Wednesday and Thursday, June 17-20. There will be a championship flight and also A, B, and C flights. Prizes will be awarded in all classes.

Papers Available in Mimeographed Form

UNTIL current supplies are exhausted, copies of the papers listed are available in mimeographed form at a cost of 25 cents per copy to members; and at 50 cents per copy to non-members. Orders should specify the name of the author as well as the title of the paper desired.

Orders must be accompanied by remittance and should be addressed to Sessions Secretary, Society of Automotive Engineers, 29 West 39th St., New York, N. Y.

Alden, C. R.
Design and Development of Injection Apparatus for High Speed Diesels

Altman, Peter
Sales and Technical Problems of Private Commercial Airplanes

Ballard, J. H., and Moore, N. A.
How the Design of Some Motor Parts Can Influence Piston Ring Performance

Ballard, J. H., Nixon, S., and Moore, N. A.
Piston Rings: Factors Contributing To Their Normal and Abnormal Wear

Barish, Thomas
Bearings for Controllable Propellers

Blanchard, H. F.
A Discussion of 1935 Cars

Bockius, C., and Hunt, J. Harold
Brake Drum and Lining Development

Britton, Roy F.
Taxation and Regulation as Applied to Highway Transportation

Brown, Lowell H., and Herbert Chase
Streamlining—Up-to-date Facts and Developments

Bull, A. W.
Rubber and Its Uses in Transportation

Burwell, A. W. and Camelford, J. A.
A New Idea in Lubrication

Bushnell, S. W.
Automotive Oil

Camp, R. H.
The Supercharger

Clinton, G. E.
Problems of Industry in Using the Highways

Cram, R. L.
The Measurement of Landing Speed and Other Flight Test Procedure

Creson, W. K.
Steering Safely

Croll, P. R., and DuBey, L. E.
How to Finish a Truck

Debbink, H. S.
Some Factors Influencing Gasoline and Oil Consumption

De Forest, A. V.
Surface Integrity and Dynamic Strength

DeSmet, E. C.
The Practical Side of Planography

Dick, Burns
Hydraulic Brake Actuation

Dunbar, H. W.
1934 Developments in Cam and Cylindrical Grinding

Fassler, P. W.
Modern Resistance Welding in the Automobile Industry

Foster, A. L.
Prospects for Future Diesel Fuels, and Their Available Supply

Gebhardt, W. A.
A Study of the Efficiencies of Overdrive Units Used in Passenger Cars

Geisse, J. H.
Air Transportation Equipment for the Private Owner

Geniesse, J. C.
Fuel and Oil Economy for the Operator

Greene, C. F.
Aircraft Structural Design and Its Influence on Other Engineering Design

Gurney, E. R., and Brown, L. H.
Technical and Economic Phases of Railroad Automotive Development

Hardy, F. I.
Economic Application of Rates for Movement of Freight by Motor Trucks

Havill, C. H.
Theory and Characteristics of Eclipse Automatic Variable Pitch Propeller

Horine, M. C.
Motor Truck Transportation—Its Development and Future Possibilities

Jardine, Robert, and Jardine, R. S.
Design and Materials for Valves and Related Parts for Maximum Service

Lampton, G. T.
The Design Requirements of Mechanical Controllable Propellers

Larsen, A. E.
The Future of the Autogiro for the Private Flyer

Larson, C. M.
The Realm of Extreme Pressure Lubricants

Leeds, Norman, Jr.
Problems in Heavy Duty Automotive Brake Design and Maintenance

Littlewood, William
Operating Requirements for Transport Airplanes

Lott, E. P.
Air Transport Operations

Markham, H. B.
Trend in Taxation and Regulation of Highway Transportation

Martland, R. W., Jr.
How Car Manufacturers Can Cooperate with the Commercial Fleet Operators

McDonald, A. F.
Maintenance and Cutting Maintenance Costs

Nohavec, F. R.
Air Conditioning as Applied to Internal Combustion Engines

Nutt, Arthur
Report of C.F.R. Aviation Gasoline Detonation Subcommittee

Padgett, J. E.
Machinery and Equipment Policies in View of the Present Business Situation

Preble, T. L.
How to Buy a Truck

Probst, K. K.
Transverse Leaf, Independent Springing

Reed, James
Our Accident Prevention Method

Sampson, P. J.
Valves for Internal Combustion Engines, and Their Related Parts

Saurer, Curt
Engineering Uses of Rubber

Sloan, W. J.
Planning and Administering Highway Systems for Greatest Usefulness

Spring, F. S.
Are We Giving the Average Private Operator the Airplane Most Suitable to His Needs?

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Taylor, C. P.
Fitting the Highway to Traffic

Taylor, E. S.
Design Limitations of Aircraft Engines

Tinkham, G. L.
Truck Refrigeration with Propane

Tirrell, E. L.
Weight Distribution on Front and Rear Axles of Motor Truck

Van Deventer, F. M.
Carbon Monoxide in Moving Vehicles

Wait, Louis
Aircraft Instruments and Their Uses

Winchester, J. F.
Operation and Maintenance

Winkler, A. H.
Service Problems and Trends in Motor Vehicle Maintenance

Wise, W. F.
Single Point Boring of Cylinders and Diamond Turning of Pistons

Wolf, A. M.
Lightness in Truck Design

Wright, T. P.
Controllable Pitch Propellers—Design Considerations

News of the Society

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Fageol Speaks At Chicago

● Chicago

Two papers were presented at the May 7 meeting of the Chicago Section held at the Hamilton Club, Chicago, the first being by Harry Newman Tolles, president of Sheldon Schools, on "Human Engineering", and the second, on "Bus Trends and Design", by F. R. Fageol, president of the Twin Coach Co. The dinner attendance was 114; and the registered total attendance, 146.

In the general discussion of Mr. Fageol's paper the subjects covered included driver's position, trolley buses versus gasoline buses, use of steam and of Diesel power, use of electric and of hydraulic power-transmission, location of powerplant and motors, odors and fumes and the reasons therefor.

Hunt Describes Science Developments

● Cleveland

John H. Hunt, director of the New Devices Section, General Motors Corp., spoke to an audience of approximately 100 members and guests of the Section at the April 15 meeting in Cleveland. His subject was "Scientific Developments in the Automobile Industry." Students from the technical schools in the Cleveland area attended in large numbers for this meeting which was sponsored by A. K. Brumbaugh, chairman of the Section.

Supplements to Mr. Hunt's talk were provided by K. D. Smith, Goodrich Rubber Co., Akron, who spoke briefly on developments in the tire industry, and Orrel Parker, vice-president, Parker Wheel Co., Cleveland, who summarized the contributions to the automobile industry from the fundamental sciences.

Met. Uses Query Cards

An interesting innovation at the May meeting of the Metropolitan Section was the distribution of 3 by 5-inch white cards. On one side appeared the words "Have you a question?" Below this was space for the name and address of the questioner (optional). On the back was space for the question itself. These cards were collected after the dinner which preceded the meeting and given later to the manufacturers' representatives for reply.

note these dates

don't miss it

S. A. E. 30th Anniversary Summer Meeting

JUNE 16 to 21, 1935

at The Greenbrier, White Sulphur Springs, W. Va.

New Members Qualified

These applicants who have qualified for admission to the Society have been welcomed into membership between April 10, 1935, and May 10, 1935.

The various grades of membership are indicated by: (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate Member; (SM) Service Member; (FM) Foreign Member.

ANDERSON, A. G. (M) automotive engineer, International Harvester Co., 606 South Michigan Avenue, Chicago; (mail) 1129 North Massasoit Avenue.

BERSHAD, ALFRED (J) 1863 72nd Street, Brooklyn, N. Y.

CHENEY, SEYMOUR JEROME (J) draftsman, Bendix Products Corp., Stromberg Division, South Bend, Ind.; (mail) Post Office Box 323.

CONINE, ROBERT C. (A) refinery writer, *Oil & Gas Journal*, Oil City, Pa.; (mail) Oil City Daily Derrick.

CROUSE, R. M. (A) secretary, treasurer, Warner-Fruehauf Trailer Co., Inc., 13 East Lee Street, Baltimore, Md.

DAVISSON, GORDON E. (J) tool designer, International Harvester Co., West Pullman Works, Chicago; (mail) 10401 South Seeley Avenue.

DEVEREUX, WALLACE CHARLES (F M) managing director, High Duty Alloys, Ltd.; Magnesium Castings & Products, Ltd., Slough, Bucks, England; (mail) "Meads" Stoke Park, Bucks, England.

DOWNING, FREDERICK B. (M) division head, E. I. duPont de Nemours & Co., Jackson Laboratory, Post Office Box 525, Wilmington, Del.

DZIEWONSKI, JOSEPH JOHN (F M) engineer, charge of aeronautical engine department, Panstw, Zakl, Inzynierji, Warsaw, Poland; (mail) 6 Waszkowskiego Str.

EBNER, EMIL E. (M) superintendent, Quaker State Oil Refining Corp., Emlenton, Pa.

ENSINGER, WILLIS B. (S M) junior mechanical engineer, United States Navy Department, city of Washington; (mail) 3828 Van Ness Street, North West.

FORKER, LEE R. (J) assistant department manager, Quaker State Oil Refining Co., Oil City, Pa.

FROLICH, PER K. (M) director of research, Standard Oil Development Co., Brunswick Avenue, Linden, N. J.; (mail) Esso Laboratories, Post Office Box 485, Elizabeth, N. J.

GIBSON, R. P. (A) manager, Detroit office, Weatherhead Co., 620 Frankfort, Cleve.; (mail) 704 Fisher Building, Detroit.

GULOWSEN, KNUTE M. (A) teacher of automotive mechanics, Board of Education, City of New York, Staten Island, N. Y.; (mail) 802 Huguenot Avenue, Huguenot Park.

HALL, HARRY (M) Diesel Designer, Fairbanks, Morse & Co., Beloit, Wis.; (mail) 846 East Grand Avenue.

HARTWELL, SAMUEL A., JR. (M) manager, field service division, Pennsylvania Grade Crude Oil Assn., Oil City, Pa.; (mail) Box 96.

HAZELL, ARTHUR MILES (M) assistant general supervisor, Cudahy Packing Co., 221 North LaSalle Street, Chicago.

HEALEY, DONALD MITCHELL (F M) chief engineer, Triumph Co., Ltd., Coventry, England.

HILEMAN, PAUL D. (M) sales engineer, Thompson Products, Inc., 7881 Conant Road, Detroit.

HOLLERITH, OTTO (M) test engineer, Wright Aeronautical Corp., Paterson, N. J.; (mail) R.F.D. 1, Caldwell, N. J.

HORTON, ERWIN C. (M) chief engineer, Trico Products Corp., 817 Washington Street, Buffalo, N. Y.

HOWARD, ALFRED C. (M) assistant general manager, Fairbanks, Morse & Co., Beloit, Wis.; (mail) 1614 Emerson.

JANSON, CURT E. (A) chief mechanic, Chicago Board of Underwriters; superintendent, fire patrol equipment, Chicago Fire Insurance Patrol, 100 South Desplaines Street, Chicago; (mail) 1044 Orleans Street.

JENSEN, D. A. (A) owner, Cords Piston Rings, City of Washington; (mail) 1324 14th Street.

KELLY, CHARLES IGNATIUS (F M) chief chemist, Herbert Green & Co., Ltd., Thames House, Millbank, London S. W. 1, England.

KISBY, ERNEST W. (A) service engineer, American Brakeblok Corp., 230 Park Avenue, New York City.

KROLLE, SERGE L. (J) 115 Connecticut Avenue, Detroit.

LAPPIN, ARTHUR NORMAN (J) Pitcairn Autogiro Co., Willow Grove, Pa.

LEVAN, E. E. (A) general sales manager, Haynes Stellite Co., Kokomo, Ind.

LEWIS, MARSHALL I. (A) shop foreman, Boston Store, 23rd and Federal Streets, Chicago.

LUND, CHARLES R. (A) automotive engineer, American Oil Co., 1301 Grant Building, Pittsburgh, Pa.

MCEVOY, MICHAEL AMBROSE (F M) managing director, M. A. McEvoy, Ltd., Leaper Street Works, Derby, England.

MCINTYRE, HUGH, JR. (J) assistant chemist, Plymouth Motor Corp., Detroit; (mail) 15720 Muirland Avenue.

MILLER, WILLIAM EVERETT (A) service manager, Wilkening Mfg. Co. of Canada, Ltd., Toronto, Ontario, Canada; (mail) 5532 McKenzie Street, Vancouver, British Columbia, Canada.

MITCHELL, H. WALTER (J) chief engineer, Stromberg Motoscope Corp., 2130 Lawrence Avenue, Chicago.

MORRIS, DONALD L. (A) owner, Don L. Morris Co., Palo Alto, Calif.; (mail) 539 Alma Street.

PARKER, E. J. (A) superintendent, automotive engineering department, Hartford Accident & Indemnity Co., Hartford, Conn.; (mail) 690 Asylum Avenue.

POULIN, JOSEPH (A) president, Asbestonos Corp., Ltd., St. Lambert-Montreal, Quebec, Canada.

RAILTON, REID ANTHONY (F M) chief engineer, director, Thomson & Taylor, Ltd., Byfleet, Surrey, England.

RAJESINGHAM, CHELLIAH (A) examiner of motor cars, Office of Registrar of Motor Cars, Colombo, Ceylon.

RICE, J. BROOKS (J) draftsman, Pacific Greyhound Lines, 401 Kansas, San Francisco; (mail) 922 East 24th Street, Oakland, Calif.

RISTEEN, HORACE WILLIAM (M) assistant professor, mechanical engineer, Michigan College of Mining & Technology, Houghton, Mich.; (mail) 125 Jasper Street.

ROLPH, S. F. (A) general manager, Yale & Towne Mfg. Co., 12340 Cloverdale Avenue, Detroit.

ROSSMANN, PETER F. (M) engineer, Packard Motor Car Co., Detroit; (mail) 3716 Three Mile Drive.

SABINA, JOHN R. (M) automotive engineer, Atlantic Refining Co., 3144 Passyunk Avenue, Philadelphia.

SIERS, THOMAS WILLIAM (A) superintendent, maintenance, Canadian Airways, Ltd., Airways Building, Winnipeg, Manitoba, Canada; (mail) 634 Jubilee Avenue.

SJOLANDER, J. L. (A) experimental engineer, Cleveland Wire Spring Co., 1281 East 38th Street, Cleveland.

STAFFORD, EDMOND W. (A) general supervisor, Loose Wiles Biscuit Co., Chicago; (mail) 3659 South Ashland Avenue.

SWANSEN, THEODORE L. (M) engineer, tractor division, Allis Chalmers Mfg. Co., Milwaukee; (mail) 1406 East Boylston Street.

TEULINGS, R. LAWRENCE (A) tire service engineer, Public Service Coordinated Transport, 703 Ferry Street, Newark, N. J.

TREUTING, HERBERT R. (M) superintendent, Amaloy division, chemical engineer, charge of research, American Machine & Foundry Co., 5502 Second Avenue, Brooklyn, N. Y.

VANDE WATER, MURRAY EARL (A) president, general manager, Refining Industries, Inc., 8443 North Kerby Avenue, Portland, Ore.; (mail) 6733 South East 36th Avenue.

WALTON, G. M. (M) vice-president, engineer, Air-Maze Corp., 812 Huron Road, Cleveland.

WEBSTER, PHILIP SIDNEY (M) layout draftsman, Oliver Farm Equipment Co., Charles City, Iowa; (mail) 1107 Kelly Street.

WHETSTONE, LEE M. (A) supervisor, motor transportation, Atlantic Refining Co., 1840 Lyell Avenue, Rochester, N. Y.

WOLF, HENRY J. (A) automotive engineer, General Petroleum Co., Higgins Building, Los Angeles.

WOOD, HY (A) works manager, Canadian Johnson Motor Co., Peterboro, Ontario, Canada.

Applications Received

The applications for membership received between April 15, 1935, and May 15, 1935, are listed herewith. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ABBOTT, ERNEST J., research physicist, University of Michigan, Ann Arbor, Mich.

ALEXANDERSON, HOWARD A., junior engineer, Eclipse Aviation Corp., East Orange, N. J.

ANDERSON, DEWEY, service manager, Sunset Electric Co., Seattle, Wash.

AXELSON, OSCAR A., Captain, automotive engineer, Columbia Gas & Electric Corp., New York City.

BALSAM, ALFRED S., Major U. S. Army, Holabird Quartermaster Depot, Baltimore, Md.

BANDI, ALFRED, director, Scintilla of Canada Ltd., Montreal, Que., Canada.

BLACK, JAMES J., chief engineer, Trailer Co. of America, Cincinnati, Ohio.

BORTON, OMAR, service manager, Autocar Sales & Service Co., New York City.

BROMAN, KENNETH G., Detroit representative, Matthews Mfg. Co., Worcester, Mass.

BRUNTON, MOTT Q., president, Julius Brunton Sons Co., San Francisco, Cal.

BUTLER, HERBERT W., assistant service manager, General Motors Peninsular S. A., Barcelona, Spain.

CAPEL, C. T. S., M.B.E., engineering superintendent, South African Airways, Durban, Natal, South Africa.

CHAPMAN, JAMES ELDEN, aeronautical engineer, Northrop Aircraft Corp., Inglewood, Cal.

COMSTOCK, C. A., chief inspector, The Fafnir Bearing Co., New Britain, Conn.

CUMMING, A. A., sales engineer, Canadian National Carbon Co., Ltd., Toronto, Ont., Canada.

DALLMANN, ELMER A., sales engineer, Perfex Radiator Co., Milwaukee, Wis.

DINSLAGE, FRANZ, director, Argus Motoren Gesellschaft M.B.H., Berlin, Germany.

DUCLOS, L. C., service manager, Fageol Truck & Coach Co., Seattle, Wash.

DUFFY, PRESTON W., lubrication engineer, Sears Roebuck & Co., Chicago, Ill.

EDWARDS, RALPH D., superintendent overhaul and repair, United Air Lines, Cheyenne, Wyo.

FLANNERY, JOHN R., automobile appraiser, 71 Garden Street, West Englewood, N. J.

FLEISCHER, RUSSELL E., manager, Colyear Motor Sales Co., Seattle, Wash.

GARBERG, JAMES, engineer of plant and equipment, Minnesota Highway Department, St. Paul, Minn.

GARDNER, CLARENCE V., engineer, Hydraulic Brake Co., Detroit, Mich.

GUEST, TOM, proprietor, 1st Ave. at 25th St., Saskatoon, Sask., Canada.

HALL, GEOFFREY WILLIAM, manager engine experimental department, Fairey Aviation Co., Ltd., Hayes, Middlesex, England.

HOLLAND, T. L., president, Anglo-American Chemical Corp., Philadelphia, Pa.

HOLMES, GEORGE ANDREW, superintendent bus and truck department, Winnipeg Electric Co., Winnipeg, Man., Canada.

JEPPE, DOUGLAS PAINTON, automotive contacts, Ethyl Gasoline Corp., Baltimore, Md.

JOHNSON, GLENN W., superintendent transportation, Bowman Dairy Co., Chicago, Ill.

KELLY, H. H., senior administrative officer, U. S. Bureau of Public Roads, Washington, D. C.

KONISHI, S., chief designer of automobile department, Tokyo Gasudenki Kogyo K.K., Omori, Tokyo, Japan.

KURIHARA, TUTOMU, body designer, Nissan Zidosya Kaisya Ltd., Yokohama, Nippon, Japan.

LAMONT, H. D., treasurer, assistant manager, Asbestos Mfg. Co., Huntington, Ind.

LASSEN, NIELS, chief engineer, Ingeniör M. O. Schöyens Bilcentraler A/S, Oslo, Norway.

LEVINE, SAM, president, Hackensack Auto Parts Inc., Hackensack, N. J.

LILYGREN, ALBERT J., Pacific coast manager, Bendix Products Corp., Seattle, Wash.

MCCARRON, JOHN J., superintendent, Consolidated Telegraph & Electrical Subway Co., New York City.

MCCONNELL, CHARLES WILLIAM, research engineer, Hyvis Oils Inc., Warren, Pa.

MORRIS, BENJAMIN F., vice-president and division manager, Thomas A. Edison Inc., Kearny, N. J.

MUIR, THOMAS GIVAN, dispatcher's clerk, Shell Eastern Petroleum Products Co., New York City.

NINNES, ROGER LANDER, chief engineer, Societé des Monteurs Gnome et Rhone, Paris, France.

NOELL, MILTON JAMES, student, Oil Well Supply Co., Oil City, Pa.

O'CONNER, FRED L., sales engineer, Titeflex Metal Hose Co., Newark, N. J.

PADDON, RICHARD ERIC, workshop foreman, W. Robinson & Son, Linsmore, N.S.W., Australia.

PARKS, JOHN L., shop superintendent, Horton Motor Lines, Baltimore, Md.

PULLEYBLANK, DONALD H., aircraft engines Hurricane Aviation Corp. Detroit, Mich.

PULLMAN, ERIC CHARLES, mechanician, Young Electric Co., Young, Sask., Canada.

REINHOLD, CHARLES, technical manager, Société E.B.C. Reinhold, Geneva, Switzerland.

ROBERTSON, STRUAN F., managing director, Direct Service Stations Ltd., Toronto, Ont., Canada.

SCARAMUZZO, LOUIS A., mechanic, Tompkins Bus Corp., Staten Island, N. Y.

SCHRAMM, MILTON E., motor testing engineer, Shell Petroleum Corp., East Chicago, Ind.

SCHROETER, FRED J., JR., engineer, Ethyl Gasoline Corp., Detroit, Mich.

SCHULTZ, WILLIAM P., superintendent auto maintenance department, Wilson & Co., New York City.

SCOVILLE, CURTISS WILFRED, automotive engineer, Socony Vacuum Oil Co., Inc., Albany, N. Y.

SHEBAT, HERBERT V., engineering pilot, Wright Aeronautical Corp., Paterson, N. J.

SHELTON, JAMES A., warrant officer, U. S. Coast Guard, Washington, D. C.

SHERMAN, DON W., director of engineering, Automotive Division, A. O. Smith Corp., Milwaukee, Wis.

SORENSEN, CARL O. R., president and manager, Sorensen-Green Electric Corp., Boeing Field, Seattle, Wash.

SPANOGLE, JOHN ANDREW, research engineer, Sterling Engine Co., Buffalo, N. Y.

SPERRY, ELMER A., JR., vice-president and chief engineer, Sperry Products Inc., Brooklyn, N. Y.

SPRINGER, GEORGE A., technical service and sales, Springer-Ott Co., Portland, Oregon.

STEARMAN, GLENN A., layout drafting, Chance Vought Corp., East Hartford, Conn.

SWANSON, C. P., service manager, Hewitt Motor Co., Los Gatos, Cal.

TEETSEL, A. C., manager research, Keasbey & Mattison Co., Ambler, Pa.

URSCHALITZ, PAUL E., transportation engineer, General Motors Truck Corp., Detroit, Mich.

VINSON, ROBERT W., Wentworth & Irwin Inc., Portland, Oregon.

WHITTELSEY, RALPH KINNEY, representative, Bendix-Westinghouse Co., Seattle, Wash.

WINN, GEORGE S., district manager, Diamond T. Motor Car Co., Chicago, Ill.

WIRSHING, HERBERT, western representative, Waukesha Motor Co., Waukesha, Wis.

ZERBST, FRITZ, Ing. Betr. Director, Auto Union A-G, Werk Horch, Zwickau-Sa., Germany.

Meetings Calendar

S.A.E. 30th Anniversary Summer Meeting

The Greenbrier, White Sulphur Springs, W. Va., June 16-21, inclusive.

Baltimore—June 6

Regional Meeting at Hagerstown, Md. Subject: Fuels.

Canadian—June 21

Royal York Golf Club, Toronto.

New England—June 11

Boston—Meeting and Outing.

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Notes and Reviews

THESE items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a rule no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G. Material; H, Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.

AIRCRAFT

Tests of Nacelle-Propeller Combinations in Various Positions with Reference to Wings—Part IV—Thick Wing—Various Radial-Engine Cowlings—Tandem Propellers

By James G. McHugh. N.A.C.A. Report No. 505, 1934; 43 pp., illustrated. Price, 15 cents. [A-1]

Tests of Nacelle-Propeller Combinations in Various Positions with Reference to Wings—Part V—Clark Y Biplane Cellule—N.A.C.A. Cowled Nacelle—Tractor Propeller

By E. Floyd Valentine. N.A.C.A. Report No. 506, 1934; 17 pp., illustrated. Price, 10 cents. [A-1]

General Equations for the Stress Analysis of Rings

By Eugene E. Lundquist and Walter F. Burke. N.A.C.A. Report No. 509, 1934; 10 pp., with charts. Price, 5 cents. [A-1]

Calculations of the Effect of Wing Twist on the Air Forces Acting on a Monoplane Wing

By G. Dätwyler. N.A.C.A. Technical Note No. 520, March, 1935: 17 pp., 10 figs. [A-1]

Full-Scale Force and Pressure-Distribution Tests on a Tapered U.S.A. 45 Airfoil

By John F. Parsons. N.A.C.A. Technical Note No. 521, March, 1935; 10 pp., 9 figs. [A-1]

Tank Tests of a Model of a Flying-Boat Hull with a Fluted Bottom

By John R. Dawson. N.A.C.A. Technical Note No. 522, March, 1935; 5 pp., 6 figs.

The Aeronautical Laboratory of the Stockholm Technical Institute

By Ivar Malmer. Translated from *Teknisk Tidskrift*, 1933. N.A.C.A. Technical Memorandum No. 766, March, 1935; 17 pp., 1 table, 16 figs. [A-1]

Modification of Wing-Section Shape to Assure a Predetermined Change in Pressure Distribution

By A. Betz. Translated from *Luftfahrtforschung*, Vol. XI, No. 6, December 5, 1934; Verlag von R. Oldenbourg, München und Berlin. N.A.C.A. Technical Memorandum No. 767, March, 1935; 17 pp., 16 figs. [A-1]

The Interdependence of Profile Drag and Lift with Joukowski Type and Related Airfoils

By H. Muttray. Translated from *Luftfahrtforschung*, Vol. XI, No. 6, December 5, 1934; Verlag von R. Oldenbourg, München und Berlin. N.A.C.A. Technical Memorandum No. 768, March, 1935; 14 pp., 15 figs. [A-1]

General Theory of Aerodynamic Instability and the Mechanism of Flutter

By Theodore Theodorsen. N.A.C.A. Report No. 496; 1935. 23 pp., with tables and charts. Price, 10 cents. [A-1]

A Turbulence Indicator Utilizing the Diffusion of Heat

By G. B. Schubauer. N.A.C.A. Report No. 524, 1935; 5 pp., with tables and charts. Price, 5 cents. [A-1]

Strength Tests of Thin-Walled Duralumin Cylinders in Combined Transverse Shear and Bending

By Eugene E. Lundquist. N.A.C.A. Technical Note No. 523, April, 1935; 18 pp., 8 figs. [A-1]

(*Continued on page 32*)

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Large Major Thrust Face

This distributes the major thrust pressure over a large area, reducing unit bearing pressure and minimizing wear. Permite's major thrust face remains concentric under all operating conditions.

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Permite's reduced minor thrust area prevents skirt distortion, minimizes friction, and stabilizes piston and ring travel.

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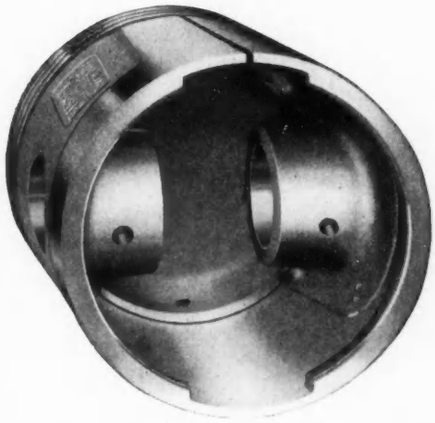

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Water Pump Parts **Permanent Mold and Semi-Permanent Mold Castings** **Piston Rings** **Aluminum Paint**

Unretouched photo showing impressions made by external type Everlock Washer when nut is set down.

Unretouched photo showing scores made by teeth as nut was unscrewed.

Unretouched photo of Everlock Washer that made above impressions and scoring. The Washer is unharmed—it is capable of repeating this operation many times.

Everlock Super Locking is readily apparent!

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NOTES AND REVIEWS

Continued

Wind-Tunnel Tests of a Wing with a Trailing-Edge Auxiliary Airfoil Used as a Flap

By Richard W. Noyes. N.A.C.A. Technical Note No. 524, April, 1935; 11 pp., 6 figs. [A-1]

The Aerodynamic Drag of Flying-Boat Hull Models as Measured in the N.A.C.A. 20-Foot Wind Tunnel—I

By Edwin P. Hartman. N.A.C.A. Technical Note No. 525, April, 1935; 9 pp., 23 figs. [A-1]

Spinning Characteristics of Wings—II-Rectangular Clark Y Biplane Cellule: 25 Percent Stagger; 0° Decalage; Gap/Chord 1.0

By M. J. Bamber. N.A.C.A. Technical Note No. 526, April, 1935; 12 pp., 23 figs. [A-1]

Bibliography of Aeronautics 1931

By the National Advisory Committee for Aeronautics. Published by the Government Printing Office, City of Washington, 1935; 312 pp. [A-3]

This bibliography, covering the aeronautical literature published from January 1 to December 31, 1931, is the most recent in the series of yearly volumes supplementing the one published by the Smithsonian Institution covering the material published prior to June 30, 1909.

The Development and Characteristics of a Long-Range Flying Boat (The S-42)

By Igor I. Sikorsky. Published in *The Journal of the Royal Aeronautical Society*, April, 1935, p. 263. [A-4]

In this lecture before the Royal Society, Mr. Sikorsky outlines his experience, problems, facts and figures in connection with the development and building of the S-42.

ENGINES

Performance Tests of a Single-Cylinder Compression-Ignition Engine with a Displacer Piston

By C. S. Moore and H. H. Foster. N.A.C.A. Technical Note No. 518, February, 1935; 14 pp., 14 figs. [E-1]

Vortex Noise from Rotating Cylindrical Rods

By E. Z. Stowell and A. F. Deming. N.A.C.A. Technical Note No. 519, February, 1935; 12 pp., 6 figs. [E-1]

Kritische Betrachtungen über Ersparnismöglichkeiten be Alten Kraftomnibussen durch Einbau von Diesel-motoren an Stelle der Vergasermotoren im Vergleich zur Umstellung der Vergasermotoren auf Gasgeneratorbetrieb

By Hans Fischbach. Published in *Automobiltechnische Zeitschrift*, Jan. 25, 1935, p. 37. [E-1]

So favorable have been the results of replacing gasoline with Diesel engines in used motorcoaches during the last 2 years in Germany, says the author, that many new motorcoaches are being equipped with Diesel engines. This article compares results of replacing carbureter engines with Diesels and with gas producer units, the cost items considered being fuel, interest charges, depreciation and repairs under conditions of varying yearly mileage.

Ease in Starting Petrol Engines from Cold

By R. Barrington and J. L. Lutwyche. Published in *The Journal of the Institution of Automobile Engineers*, May, 1935, 15. [E-4]

The authors feel that very little of the published information on the subject of cold starting is based on experience of British cars or is applicable to the conditions under which cars function in the British Isles. In this article some of the outstanding features of experience gained in cold-room testing a very large number and variety of British cars during the last five years is recorded. The aim of these tests has been to provide the cars with suitable starting mechanisms.

MATERIAL

The Physical Chemistry of Steel Making

By C. H. Herty, Jr., and Associates. Published by Mining and Metallurgical Advisory Boards, Pittsburgh, Pa., 1934. [G-1]

The investigations of the Metallurgical Advisory Board, in cooperation with the Department of Metallurgy of Carnegie Institute of Technology and the Bureau of Mines, have been centered since 1926 on "The Physical Chemistry of Steel Making." Each year for the past eight years a conference has been held in Pittsburgh to discuss informally the results of the work. The investigation has become well known throughout the metallurgical world; the work done and the results accomplished

(*Continued on page 34*)

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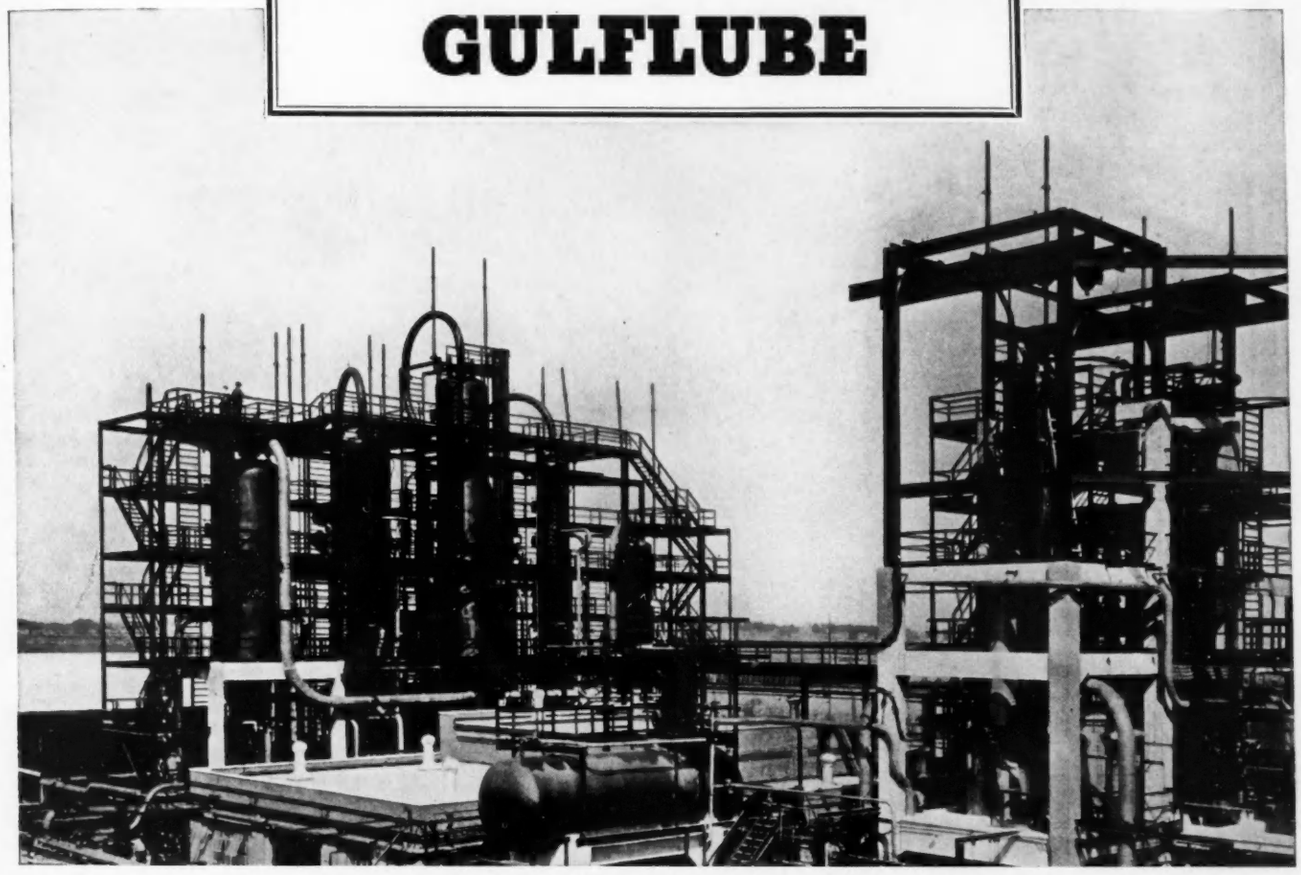

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GULF'S new Multi-sol Process now makes possible a premium oil for a quarter a quart. After months of research, Gulf chemists and technologists have perfected the Gulf Multi-sol Process which produces a remarkably clear-cut separation of the paraffinic and naphthenic portions of the oil, producing a premium quality motor oil.

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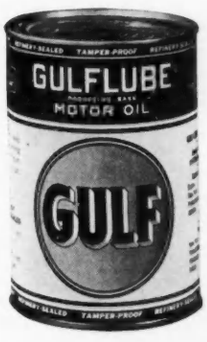

NO OTHER 25c MOTOR OIL GIVES YOU ALL THESE QUALITY POINTS

1. It is Multi-sol Processed.
2. Its already high mileage has been stepped up 20% to 25%.
3. Highly resistant to oxidation—non-sludging . . . extra long life.
4. It has a high viscosity index—thins out less under heat . . . easy starting year 'round. Thoroughly de-waxed.
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NOTES AND REVIEWS

Continued

have marked this internationally as one of the most notable instances of cooperative effort.

A resume of the details of procedure and results of the work is given in the six sections of this volume.

Proceedings of The Institution of Mechanical Engineers 1934, Vol. 127

Published by the Institution of Mechanical Engineers, London, 1934; 458 pp. [G-1]

The following papers of interest are included in this volume of the Proceedings:

The Operating Temperatures of Cast Iron and Aluminum Pistons in a 12-Inch Bore Oil Engine

By H. Wright Baker

The Work of the Alloys of Iron Research Committee

By C. H. Desch

The Embrittlement of Low-Carbon Steel

By F. C. Lea and R. N. Arnold

The Alloys of Iron and Copper

By J. L. Gregg and B. N. Daniloff. Published for *The Engineering Foundation* by the McGraw-Hill Book Company, Inc., New York and London, 1934; 454 pp., illustrated. [G-1]

This is the fourth volume of the monograph series. The aims of this and other monographs have been described in reviews of the previous volumes.

This volume has been prepared at Battelle Memorial Institute as part of the Institute's contribution to Alloys of Iron Research. Over six hundred pertinent articles on this subject were located and abstracted and of these four hundred appear in the selected bibliography at the end of the book.

Antiknock Effect of Tetraethyllead—Effectiveness of Tetraethyllead in Increasing the Critical Compression Ratio of Individual Hydrocarbons

By J. M. Campbell, F. K. Signaigo, W. G. Lovell and T. A. Boyd. Published in *Industrial and Engineering Chemistry*, May, 1935, p. 593. [G-1]

Quantitative measurements of the specific antiknock effect of tetraethyllead in sixty-two individual hydrocarbons were made by finding the increase in critical compression ratio, in a single-cylinder variable-compression engine, made possible by the addition of tetraethyllead in a concentration of 1.0 cc. per gallon. Upon this basis there are as many as twenty fold variations in the effectiveness of tetraethyllead in suppressing knock in different hydrocarbons. Certain general relationships between hydrocarbon structure and susceptibility to lead which appear to be consistent within the scope of this work are described.

Unsoundness in Aluminum Sand Castings—Part III Solidification in Sand Moulds under Pressure

By D. Hanson and I. G. Slater. Presented at the March 6-7, 1935 meeting of the Institution of Mechanical Engineers, London. [G-1]

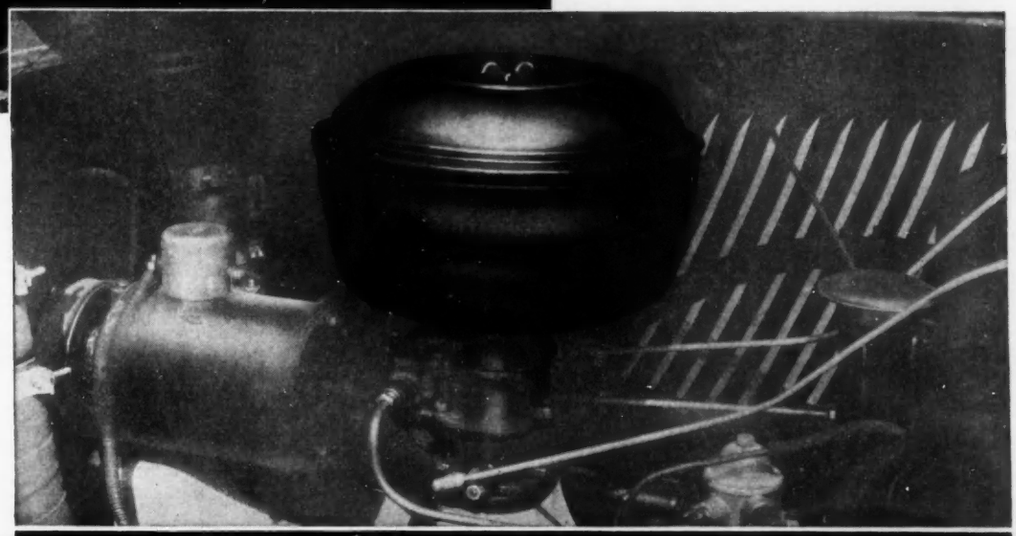
By allowing gassy aluminum-alloy melts to solidify in sand moulds under an extraneous pressure of air or nitrogen, pinholes were reduced in size and ingots of high density obtained. The applied pressure appears to affect the gas cavities by compressing them to finer dimensions, the authors explain, adding that the mechanical properties of the alloys are much improved by solidification under pressure, while shrinkage is confined to a single cavity.

Fire Resistant Doped Fabric for Aircraft

By Gordon M. Kline. Published in *Industrial and Engineering Chemistry*, May, 1935, p. 556. [G-1]

The author points out that cellulose nitrate dope now commonly used to cover the fabric on the wings and fuselage of airplanes is very flammable and its replacement by a less hazardous product is desirable. The development of a satisfactory nonflammable dope by the use of natural and synthetic resins with cellulose nitrate and cellulose acetate has not proved feasible. An airplane covering with very good resistance to ignition may be obtained by the application of a 3 to 7 boric acid-borax mixture to airplane cloth and subsequently doping it with cellulose acetate. Cellulose acetate dope is now only moderately more expensive than cellulose nitrate dope, Mr. Kline argues, and the cost difference becomes insignificant when the lower fire hazard resulting from the use of the much less flammable cellulose acetate dope is considered.

(*Concluded on page 36*)



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NOTES AND REVIEWS

Continued

Moisture Relations of Aircraft Fabrics

By Gordon M. Kline. Published in *Journal of Research of the National Bureau of Standards*, January, 1935, p 67. [G-1]

The amount of moisture held at various relative humidities and the rate of absorption of this moisture were determined for airplane and balloon cloths, airplane fabric doped with cellulose nitrate, outer-cover fabric doped with cellulose acetate, dope films, and gas-cell fabrics.

Stockpunkt, Fliessbeginn und Viskosität der Schmieröle für Kraftfahrzeuge

By J. Formánek. Published in *Automobiltechnische Zeitschrift*, Feb. 10, 1935, p. 71. [G-1]

The solidifying point, pourpoint and viscosity of 16 different crankcase oils were determined according to 2 German and the A.S.T.M. methods, here described. Further, methods developed by the German Institute for Aeronautical Research were used to make a fourth determination of pourpoint and viscosity. The conclusion drawn is that in judging crankcase oils, the pourpoint and viscosity at 0 deg. cent. should be determined as well as the solidifying point.

Bibliography of Non-Metallic Inclusions in Iron and Steel

Compiled by Lois F. McCombs and Morris Schrero. Cooperative Bulletin 70. Published by Mining and Metallurgical Advisory Boards, Pittsburgh, Pa., 1935; 308 pp. [G-3]

This bibliography was prepared by the Technology Department of the Carnegie Library of Pittsburgh particularly for use in connection with the program of investigations on "The Physical Chemistry of Steel Making" which has been carried on since 1926 under the auspices of Carnegie Institute of Technology and Mining and Metallurgical Advisory Boards. It is concerned with a subject on which printed information is widely scattered, specific information often concealed under general subjects, and the terminology extremely confused.

Proceedings Fifteenth Annual Meeting American Petroleum Institute, Dallas, Texas, November, 1934, Division of Refining, Section III

Published by the American Petroleum Institute, New York, 1934; 156 pp. [G-3]

Section III of the Proceedings contains a number of papers of automotive interest including:

The Evaluation of the Ignition Characteristics of Diesel-Engine Fuel Oils

By C. C. Moore, Jr., and G. R. Kaye

Outlook for the Automotive High-Speed Diesel Engine in Heavy-Duty Transport

By Joseph Geschelin

Rail-Car Fuel Possibilities

By D. P. Barnard

The 1934 Detonation Road Tests—Report of Cooperative Fuel Research Committee

Presented by C. B. Veal

Lubrication of Solid-Injection Diesel Engines

By W. G. G. Godron

Commercial Situation of Automotive Extreme-Pressure Lubricants

By H. C. Mougey

The Structure of Liquids and the Mechanism of Viscosity

By W. K. Lewis and Lombard Squires

Improved Motor Oils

By M. Otto, F. L. Miller, A. J. Blackwood and G. H. B. Davis.

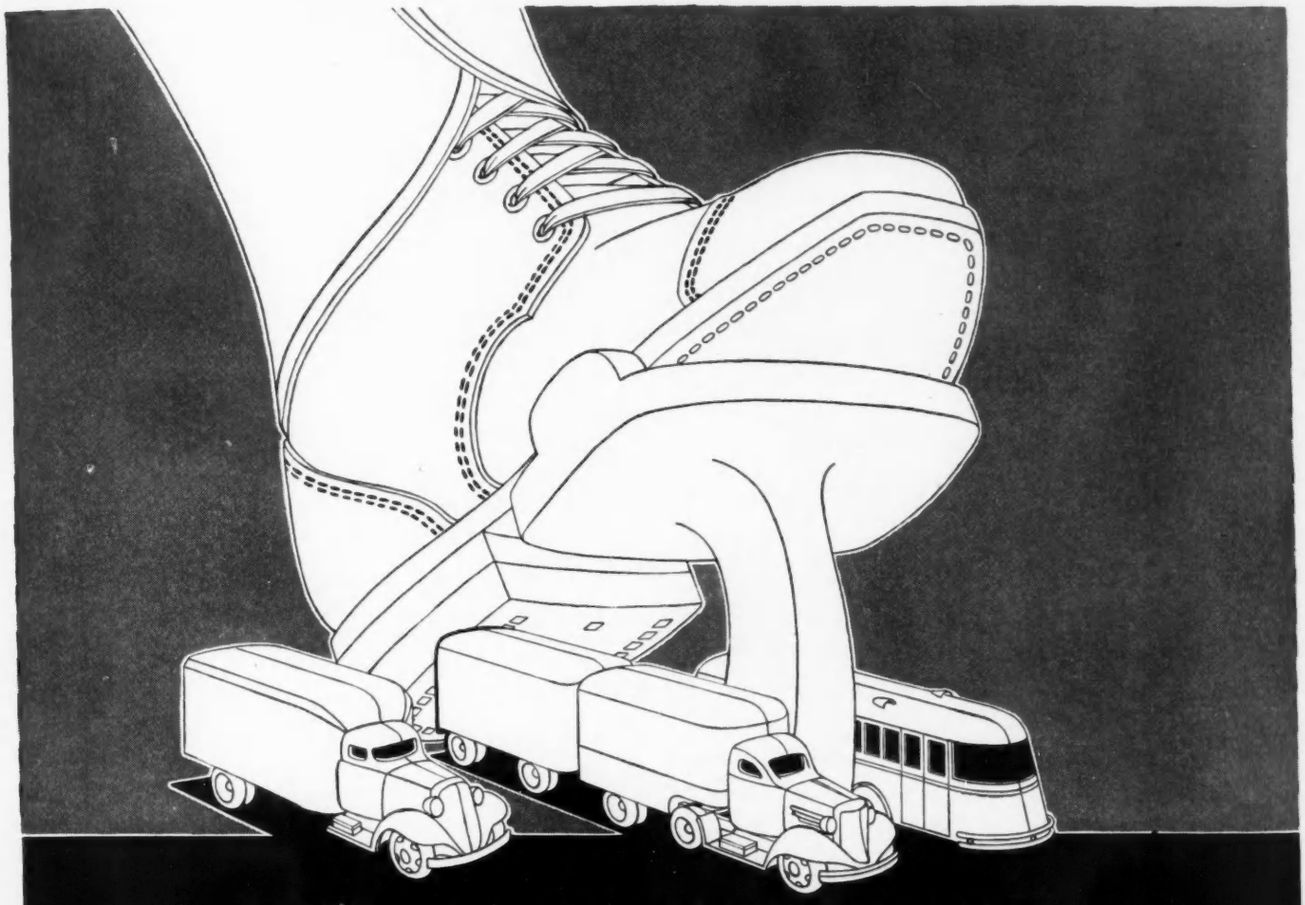
MISCELLANEOUS

Manual of Gear Design—Section One
Spur and Internal Gears—Section Two

By Earle Buckingham. Published by *Machinery*, New York, 1935; 183 and 168 pp. respectively. [H-1]

Section One is comprised of eight place tables of angular functions in degrees and hundredths of a degree and tables of involute functions, radians, gears ratios and factors of numbers, reproduced by the photo-offset process directly from the original manuscript insuring accurate reproduction of the numerous tables. These have been prepared by

(Concluded on page 38)



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NOTES AND REVIEWS

Concluded

Professor Buckingham of the Massachusetts Institute of Technology and approved by the American Gear Manufacturers' Association.

Section two covers the design of spur and internal gears and the author expects to complete eventually sections relating to other commonly-used types of gears.

The object of the Manual of Gear Design is to provide one single and complete source of reference for the solution of problems of gear design.

Practical Solution of Torsional Vibration Problems

By W. Ker Wilson. Published by John Wiley & Sons, Inc., New York and London, 1935; 438 pp. [H-1]

The author points out that the ideal system should exhibit no perceptible vibratory disturbance throughout the normal operating speed range, a requirement which is now an important consideration in the design of automobile transmission systems. The rapid development of the internal combustion engine for marine propulsion is another factor mentioned as responsible for bringing the torsional vibration problem into prominence.

This book has been written in an attempt to set down the principles and computation details of the subject in a manner suitable for everyday reference.

The selection and arrangement of the subject-matter are based on several years' practical experience in carrying out torsional vibration investigations on many different types of installation; and the methods which are developed, Mr. Wilson states, have been found reliable in practice.

Werkzeugmaschinen und Reparaturgeräte auf der Automobilausstellung

Published in *Automobiltechnische Zeitschrift*, March 10, 1935, p. 130. [H-3]

Descriptions are given of the production and repair equipment shown at the recent Berlin show, including cylinder finishing equipment, grinders, boring machines, electric hand tools, polishing and lubricating equipment, car jacks, electric testing devices and tire repair equipment.

Der Deutsche Kraftfahrzeugabsatz 1934

By Cornelius Castorp. Published in *Automobiltechnische Zeitschrift*, March 10, 1935, p. 113. [H-6]

That the number of new passenger cars licensed in Germany in 1934 was more than 50 per cent greater and the number of new motor-trucks was more than 100 per cent greater than in 1933 are the outstanding points in this study of the German automotive market in 1934. For these two classes the figures were greater than for any of the four preceding years. New motorcycles, while showing an increase over 1933, were fewer than in 1931. The totals for 1933 and 1934 are analyzed according to make and size of vehicle.

PASSENGER CAR

Notes sur les Nouvelles Formes de Voitures

By P. Maillard. Published in *La Technique Automobile et Aérienne*, 1st quarter, 1935, p. 11. [L-1]

That current streamlined cars are far less efficient than is generally believed and that the attainment of the hoped for efficiency will come only when design is freed from the necessity of conforming to the conventional shaped chassis is the author's thesis. He develops the merits of a triangular shaped chassis with a single forward steering wheel and discards this in favor of a lozenge-shaped chassis with both a forward and a rear steering wheel.

Die IAMA 1935

By Wa. Ostwald. Published in *Automobiltechnische Zeitschrift*, Feb. 20, 1935, p. 82. [L-1]

The character of exhibits at the recent Berlin show is an extremely favorable augury of the rapid motorization of Germany in the near future, in the opinion of this commentator. The vehicles were distinguished not by radical design changes, but by features of proved worth and by advances in the technique of material and production.

Two types of motorcycles are distinguished, one for sport, and one a cheap utility machine. Among passenger vehicles, the small car class, with one laughably cheap, extremely small and distinctly efficient type and three high-speed sport makes, looms as the most important. A tendency toward open bodies is seen in the larger sport models. Streamlining is conspicuous in the large utility passenger-car models. Motor-truck progress is marked in the entire range from gigantic six-wheeler to the small single cylinder Diesel tractor. High speed and new forms of general layout distinguish the new motorcoaches.

In addition to this general summary of show developments, this issue of *Automobiltechnische Zeitschrift* contains articles dealing individually with each class of vehicle.